



Digitized by the Internet Archive
in 2025

THE annual volumes of Papers of the Michigan Academy of Science, Arts, and Letters are issued under the joint direction of the Council of the Academy and of the University of Michigan Press. The editor for the Academy is Alfred H. Stockard; for the University, Eugene S. McCartney.

Previous publications of The Michigan Academy of Science, now known as The Michigan Academy of Science, Arts, and Letters, were issued under the title, Annual Report of the Michigan Academy of Science. Twenty-two volumes were published, of which those numbered 1, 7, 21, and 22 are out of print. Copies of the other volumes are still available for distribution and will be sent on exchange as long as the editions last. Applications for copies should be addressed to the Librarian of the University of Michigan.

The Annual Reports which are now being published contain the proceedings of the Academy. Applications for copies should be addressed to the Librarian of the University of Michigan.

The prices of previous volumes of the Papers are listed at the end of this volume. Orders for volumes and requests for detailed book lists of other University of Michigan publications should be addressed to the University of Michigan.

MICHIGAN ACADEMY OF SCIENCE
ARTS AND LETTERS

VOLUME XXII

CONTAINING PAPERS SUBMITTED AT THE ANNUAL
MEETING IN 1936

PAPERS
OF THE
MICHIGAN ACADEMY OF SCIENCE
ARTS AND LETTERS

EDITORS
EUGENE S. McCARTNEY
UNIVERSITY OF MICHIGAN
ALFRED H. STOCKARD
UNIVERSITY OF MICHIGAN

VOLUME XXII

"Pusilla res mundus est nisi in illo
quod quaerat omnis mundus habeat."
— SENECA, *Naturales Quaestiones*

Ann Arbor
UNIVERSITY OF MICHIGAN PRESS
1937
All rights reserved

COPYRIGHT, 1937,
BY THE UNIVERSITY OF MICHIGAN

Set up and printed,
May, 1937
Published June, 1937

PRINTED IN THE UNITED STATES OF AMERICA
BY THE PLIMPTON PRESS • NORWOOD • MASS.

RECOGNITION

IN THE spring of 1931 there applied for a position in my office a young woman who had had no professional training or experience in the handling of manuscripts and the making of books, but who did have boundless enthusiasm for such work. I gave her the position because of her enthusiasm.

Owing to pressure from other sources I was compelled from the very first to entrust to her a great deal of the responsibility for the *Academy Papers* and other volumes, a burden which she capably bore. Her powers grew from year to year, and she became a big help in removing the editorial briars of my workaday world.

The editing of books composed by many hands is exacting and requires unremitting vigilance. Each *Academy* volume contains some fifty articles, in which eight or ten widely different fields of investigation are represented. Only a person who has threaded his way through a similar maze of manuscripts and the proof can realize what unceasing demands a volume makes upon one's time, energy, patience, tact, and resourcefulness. With unfailing courage and cheerfulness my assistant, Mrs. Hilda J. Straw, dedicated herself to her work, and it would be ungracious for me to allow to go unrecorded the contribution of one who has bound in eight *Academy* volumes so much loyalty and ability. Since Mrs. Straw has given up her work at the University and is now making her home in Tennessee I take pleasure in paying her a tribute as lasting as the final volume upon which she worked. I am sure that authors will join with me in regretting her departure and in wishing her lasting joy and happiness.

I avail myself of this opportunity to express in print the appreciation of the *Academy* and the University for the continued interest and coöperation of the Plimpton Press. The pride which each member of the staff seems to feel in helping to make the volumes first class has been a constant source of encouragement and has served, not infrequently, to renew flagging spirits.

E. S. McC.

OFFICERS FOR 1936

President

A. M. CHICKERING

Albion College

Vice-President

LEE R. DICE

University of Michigan

Section Chairmen

ANTHROPOLOGY, R. Clyde Ford, Michigan State Normal College

BOTANY, H. H. M. Bowman, University of Toledo

ECONOMICS AND SOCIOLOGY, Samuel M. Levin, Wayne University

FORESTRY, P. W. Robbins, Michigan State College

GEOGRAPHY, W. J. Berry, Western State Teachers College

GEOLOGY AND MINERALOGY, R. L. Belknap, University of Michigan

HISTORY AND POLITICAL SCIENCE, Harlow J. Heneman, University of Michigan

LANGUAGE AND LITERATURE, Hereward T. Price, University of Michigan

MATHEMATICS, J. B. Brandeberry, University of Toledo

PHILOSOPHY, John M. De Haan, Michigan State College

PSYCHOLOGY, Wm. F. C. Krueger, Wayne University

SANITARY AND MEDICAL SCIENCE, Frederick W. Fabian, Michigan State College

ZOÖLOGY, Frank E. Eggleton, University of Michigan

Secretary

L. J. Young, University of Michigan

Treasurer

E. C. Prophet, Michigan State College

Editor

A. H. Stockard, University of Michigan

Librarian

W. W. Bishop, University of Michigan

CONTENTS

ANTHROPOLOGY

	PAGE
NOTES ON THE PREPARATION AND THE USES OF BASSWOOD FIBER BY THE INDIANS OF THE GREAT LAKES REGION. Volney H. Jones	1
NOTES ON INDIAN TRADE SILVER ORNAMENTS IN MICHIGAN. George I. Quimby, Jr.....	15

BOTANY

MINIMUM INTENSITY OF ARTIFICIAL ILLUMINATION EFFECTIVE IN SUPPLEMENTING THE NORMAL PHOTOPERIOD. J. Perry Austin..	25
ANATOMY OF THE LEAF TRANSITION REGION OF <i>URGINEA MARITIMA</i> . Dorothy Chapman Carpenter.....	27
VEGETATION OF THE PORCUPINE MOUNTAINS, NORTHERN MICHIGAN. PART II. FLORISTICS. Henry Townsend Darlington.....	33
GROWTH RESPONSES OF VARIOUS PLANTS TO INDOLE 3-N-PROPIONIC ACID. Sam Granick and Harman W. Dunham.....	69
PROLIFERATION AND RENEWAL OF GROWTH IN SUPPRESSED FRUITS IN TOMATOES. Felix G. Gustafson.....	79
WHEN DOES A PINE TREE COMPLETE ITS SEASONAL GROWTH? Felix G. Gustafson.....	83
ADDITIONS TO THE FLORA OF CHIPPEWA COUNTY, MICHIGAN. Frederick J. Hermann.....	85
ADDITIONS TO THE FLORA OF WASHTENAW COUNTY, MICHIGAN. II. Frederick J. Hermann.....	91
A POLLEN ANALYSIS OF A BOG IN NORTHERN ONTARIO. Elsie Janson and Elizabeth Halfert.....	95
NEW MARINE ALGAE FROM WASHINGTON. Chin-Chih Jao.....	99
NOTES ON NEW OR UNUSUAL MICHIGAN DISCOMYCETES. IV. Bessie B. Kanouse.....	117
CELL OUTGROWTHS FROM WOUNDED SURFACES OF PLANTS IN DAMP ATMOSPHERES. Carl D. La Rue.....	123
FRESH-WATER ALGAE FROM TEXAS. Lois C. Lillick.....	141
RUSTS FROM THE LOWER RIO GRANDE VALLEY, TEXAS. Edwin B. Mains.....	153
FORMATION OF PERIDERM IN THE ENDOSPERM OF <i>CRINUM ASIATICUM</i> . James Merry.....	159
A STUDY OF THE WATER MOLDS OF THE LYDELL STATE FISH HATCHERY AT COMSTOCK PARK, MICHIGAN. Edwin Y. Monsma.....	165
BRYOPHYTES OF THE PORCUPINE MOUNTAINS, ONTONAGON COUNTY, MICHIGAN. George E. Nichols and William C. Steere.....	183

	PAGE
PRELIMINARY NOTES ON THE DESMIDS OF ISLE ROYALE, MICHIGAN. Gerald W. Prescott.....	201
UNUSUAL AGARICS FROM MICHIGAN. IV. Alexander H. Smith.....	215
NOTES ON NORTH ATLANTIC MARINE ALGAE. I. Wm. Randolph Taylor	225
VEGETATIVE ANATOMY OF THE TOMATO (<i>LYCOPERSICUM ESCULENTUM</i> MILL.). II. LEAF STRUCTURE. Edward F. Woodcock.....	235

ECONOMICS AND SOCIOLOGY

MARX VS. MALTHUS. Samuel M. Levin.....	243
A DECADE AND A HALF OF AMERICAN AGRICULTURAL POLICY. Harald S. Patton.....	259

FORESTRY

SOME RESUPINATE POLYPORES FROM THE REGION OF THE GREAT LAKES. VIII. Dow V. Baxter.....	275
TESTS USED IN COMPARING BACK PUMPS. Ronald L. Bird.....	297
RELEASE CUTTINGS IN PLANTATIONS OF WHITE AND NORWAY PINE. Leigh J. Young and Francis H. Eyre.....	301

GEOGRAPHY

THE GEOGRAPHIC FACTOR IN THE DISTRIBUTION, TRENDS, AND PEAKS OF THE POPULATION OF PUERTO RICO, 1900-1930. Lyman D. Bothwell.....	321
A STUDY OF THE ORIGINAL VEGETATION OF WAYNE COUNTY, MICHIGAN. W. Bruce Dick.....	329
THE CHOROLOGY OF THE CLAREMONT-SPRINGFIELD REGION IN THE UPPER CONNECTICUT VALLEY IN NEW HAMPSHIRE AND VERMONT. Stanley D. Dodge.....	335
THE UMLAND OF HOWELL, LIVINGSTON COUNTY, MICHIGAN. Stanley D. Dodge and Leonard S. Wilson.....	355
THE SLOPE AND SLOPE-DIRECTION MAP. Robert M. Glendinning ..	359
A MAP OF SETTLEMENT AGGLOMERATION AND DISSEMINATION IN JAPAN. Robert Burnett Hall.....	365
THE SURFACE CONFIGURATION OF SOUTH AMERICA. Preston E. James	369
NOTES ON THE POPULATION OF FRANCE, WITH SPECIAL REFERENCE TO THE POPULATION OF THE AQUITAIN BASIN. Henry Madison Kendall.....	373
SOME TYPES OF RECREATIONAL LAND USE IN MICHIGAN. A SERIES OF TYPE STUDIES. Edward C. Prophet.....	385
FUNCTIONAL AREAS OF DETROIT, 1890-1933. Leonard S. Wilson...	397

GEOLOGY AND MINERALOGY

GLACIAL-LAKE LEVELS INDICATED BY TERRACES OF THE HURON, ROUGE, AND CLINTON RIVERS, MICHIGAN. James William Bay	411
---	-----

Contents

ix
PAGE

THE CAMBRIAN-OZARKIAN CONTACT IN ALGER COUNTY, MICHIGAN.	
Stanard G. Bergquist.....	421
DUNES OF THE HERRING LAKE EMBAYMENT, MICHIGAN. Irving D.	
Scott and Kenneth W. Dow.....	437

HISTORY AND POLITICAL SCIENCE

THE JUSTICES OF THE PEACE AND THE ROYAL PREROGATIVE IN THE REIGN OF JAMES I. Egbert R. Isbell.....	451
THE FRENCH ELECTION OF 1871. Rudolph A. Winnacker.....	477

LANGUAGE AND LITERATURE

LIDDELL'S LAWS OF ENGLISH RHYTHM. Amos R. Morris.....	485
PARADISE REGAINED. Warner G. Rice.....	493

PHILOSOPHY

THE NATURE OF THE QUESTION, "ARE THERE THREE CONSECUTIVE 7'S IN THE EXPANSION OF Π ?" Alice L. Ambrose.....	505
--	-----

PSYCHOLOGY

THE NEUROTIC MURDERER. Lowell S. Selling.....	515
---	-----

ZOÖLOGY

EGGS AND NATURAL NESTS OF THE EASTERN RINGNECK SNAKE, <i>DIADOPHIS PUNCTATUS EDWARDSII</i> . Frank N. Blanchard.....	521
CONTRIBUTIONS TO TEXAN HERPETOLOGY. V. SPINY AND SCALY LIZARDS (<i>SCELOPORUS</i>). Charles E. Burt.....	533
ANYPHAENIDAE OF BARRO COLORADO ISLAND, PANAMA CANAL ZONE. Arthur M. Chickering.....	541
AGE, GROWTH, AND MORPHOMETRY OF THE CISCO, <i>LEUCICHTHYS</i> <i>ARTEDI</i> (LE SUEUR), IN BLIND LAKE, WASHTENAW COUNTY, MICHIGAN. Gerald P. Cooper.....	563
THE EMBRYOLOGY OF THE SPLEEN IN <i>AMIA CALVA</i> . Harvey De Bruine PRODUCTIVITY OF THE PROFUNDAL BENTHIC ZONE IN LAKE MICHIGAN. Frank E. Eggleton.....	593
SOME CHARACTERISTICS OF A POPULATION OF STUNTED PERCH. R. William Eschmeyer.....	613
A PRELIMINARY REPORT ON THE PAST AND PRESENT STATUS OF THE MOOSE, <i>ALCES AMERICANA</i> (CLINTON), IN MICHIGAN. Paul Hickie	629
FURTHER OBSERVATIONS AND STATISTICS ON THE FLIGHT OF FISHES. Carl L. Hubbs.....	641
IODINE AND THE PRODUCTION OF PERMANENT TADPOLES IN THE FROG (<i>RANA PIPIENS</i>). Jessie L. Metcalf and Charles W. Creaser....	661

	PAGE
BIOLOGY OF THE BOXWOOD LEAF MINER (<i>MONARTHROPALPUS BUXI</i> LABOU) IN MICHIGAN. Donald T. Ries.....	665
STUDIES ON THE FEMALE REPRODUCTIVE SYSTEM OF THE PRAIRIE DOG, <i>CYNOMYS LEUCURUS</i> . II. NORMAL CYCLIC PHENOMENA OF THE OVARIAN FOLLICLES. Alfred H. Stockard.....	671
THE AGE, GROWTH, AND SEX RATIO OF THE LAKE SUPERIOR LONGJAW, <i>LEUCICHTHYS ZENITHICUS</i> (JORDAN AND EVERMANN). John Van Oosten.....	691

ILLUSTRATIONS

PLATES

ANTHROPOLOGY

PLATE	FACING PAGE
I. Preparation of basswood fiber by Indians for cordage, thongs, and weaving material.....	14
II. Fig. 1. Ball of completed cord of basswood inner bark...	14
Fig. 2. Roll of basswood inner bark prepared for boiling	
III. Indian trade silver ornaments found in Michigan.....	24

BOTANY

IV. Transition region of the Urginea leaf	28
V-VI. Vegetational features of the Porcupine Mountains, northern Michigan.....	68
VII-VIII. Growth responses of plants to indole 3-n-propionic acid.....	78
IX-XI. Photographs illustrating unusual growth in tomato plants.....	82
XII-XIV. Marine algae from Washington.....	116
XV-XVI. Michigan Discomycetes.....	122
XVII-XVIII. Fresh-water algae from Texas.....	152
XIX. Desmids from Isle Royale, Michigan.....	213
XX-XXIV. Michigan agarics.....	224
XXV-XXVII. North Atlantic marine algae.....	234
XXVIII-XXX. Anatomy of the tomato.....	242

FORESTRY

XXXI-XXXVII. Species of resupinate polypores.....	296
---	-----

GEOGRAPHY

XXXVIII-XLIII. Photographs illustrating the chorology of the Claremont-Springfield region of the upper Connecticut valley.....	354
--	-----

GEOLOGY

XLIV. Views of terrace of Lake Wayne age cut in delta terrace of Lake Warren age.....	412
XLV-XLIX. Falls in Alger County, Michigan.....	436
L. Fig. 1. Façade of Pictured Rocks, Alger County.....	436
Fig. 2. Miner's Castle, Alger County	

PLATE		FACING PAGE
LI.	Chapel Falls, Alger County.....	436
LII.	Fig. 1. Lower Herring Lake, Benzie County, Michigan, and truncated dunes on north bay-mouth bar.....	450
	Fig. 2. Lower Herring Lake and southern dune area ad- jacent to it	

ZOÖLOGY

LIII - LVII.	Eggs and nests of the eastern ringneck snake.....	532
LVIII - LIX.	External anatomy of the spider.....	562
LX - LXI.	Scales of <i>Leucichthys artedi</i>	572
LXII - LXIV.	Figures illustrating the embryology of the spleen in <i>Amia calva</i>	592
LXV.	Stunted perch.....	628
LXVI.	Fig. 1. Perch showing parasitism.....	628
	Fig. 2. Scale from slow-growing perch	
LXVII - LXVIII.	Pupa, larva, and adult insect of the boxwood leaf miner, together with parts of the body.....	670
LXIX.	Leaves showing adults and pupae of the leaf miner emerging; infested and uninfested leaves; eggs greatly enlarged.....	670
LXX - LXXII.	Female reproductive system of the prairie dog..	690

FIGURES IN THE TEXT

ANTHROPOLOGY

FIGURE		PAGE
1.	Design elements and pictures engraved upon silver ornaments of Indians.....	19

BOTANY

2.	Graph showing growth of <i>Pinus sylvestris</i>	84
3.	Pollen profile for a bog in northern Ontario.....	96
4.	Cell outgrowths from wounded leaves of plants.....	125
5.	Production of cell outgrowths in leaves of <i>Mitchella repens</i> by the application of heteroauxin.....	129
6.	Figures showing normal periderm on surface of mature seed of <i>Crinum asiaticum</i> , normal internal tissue of endosperm of mature seed, and wounded surface of endosperm.....	162
7.	Figures showing microscopic characters of Michigan agarics ..	216
8.	Primary and secondary leaves of a tomato plant.....	236

GEOGRAPHY

9.	Diagrammatic studies of Wayne County, with bar graphs showing proportion of oak, hickory, beech, and maple trees by sections and with line graphs indicating relief and soils..	333
10.	Graph of population growth for France by five-year periods..	374

GEOLOGY

FIGURE	PAGE
11. Typical valley profiles showing location of former mouths of rivers.....	416

ZOÖLOGY

12. Histogram showing number of eggs in 202 complements of the eastern ringneck snake.....	527
13. Relation between length of female eastern ringneck snakes and number of eggs produced.....	528
14. Dimensions of eggs of eastern ringneck snakes.....	530
15. Growth curve for Blind Lake ciscoes based on average lengths at the conclusion of each growing season.....	568
16-18. Depth distribution of benthic animals in Lake Michigan, 1931 and 1932.....	596, 597, 599
19-20. Seasonal distribution of benthic fauna in Lake Michigan, 1931 and 1932.....	600, 601
21. Directions taken in flight by flying fish frightened into the air by a steamer, as related to direction of wind.....	646
22. Average weight in ounces of the males and the females of seven age groups of the Lake Superior longjaw.....	695
23. Growth curves of the Lake Superior longjaw.....	697
24. Percentage of total growth in length and weight completed by the Lake Superior longjaw in different years of life.....	700
25. Length-weight relationship of the Lake Superior longjaw.....	703

MAPS

GEOGRAPHY

MAP	
1. Distribution of population in Puerto Rico, 1930.....	323
2. Population peak dates in Puerto Rico, 1899, 1910, 1920, 1930....	324
3. Trends of population in Puerto Rico since 1899.....	324
4. Original vegetation of Wayne County, Michigan.....	330
5. Claremont-Springfield umland, New Hampshire and Vermont....	336
6. Population growth and decline of Claremont-Springfield umland .	340
7. Howell umland, Livingston County, Michigan, showing road turnings.....	356
8. Slope map of a sample area.....	360
9. Slope and slope-direction map.....	360
10. Slope, slope direction, and land use.....	362
11. Slope, slope direction, land use, and erosion.....	363
12. Settlement agglomeration and dissemination in Japan.....(after)	366
13. Surface configuration of South America.....(after)	370
14. Population changes in France, 1801-1931.....	375

MAP	PAGE
15. Percentage of total population of France engaged in agriculture, 1931.....	376
16. Percentage of total population of France engaged in industry, 1931.....	377
17. Agricultural-industrial indices for France, 1851.....	378
18. Agricultural-industrial indices for France, 1901.....	379
19. Agricultural-industrial indices for France, 1931.....	380
20. Population density of France, 1931.....	381
21. Surface divisions of the Aquitaine basin.....	382
22. Areas of declining population superimposed on surface divisions of the Aquitaine basin.....	383
23. Transportation routes to northern Michigan and the location of type studies of recreational land use.....	386
24. Escanaba, Delta County, Michigan.....	388
25. Munising and vicinity, Alger County, Michigan.....	389
26. St. Ignace and Les Cheneaux Islands, Mackinac County, Michigan.....	391
27. Pigeon River tract in Otsego and Cheboygan counties, Michigan.....	393
28. Functional map of Detroit, 1890.....	399
29. Major street pattern of Detroit.....	400
30. Functional map of Detroit, 1900.....	402
31. Functional map of Detroit, 1910.....	404
32. Functional map of Detroit, 1920.....	407
33. Functional regions of Detroit, 1933.....	409

GEOLOGY

34. Relative positions of areas in which glacial lake levels are indicated by terraces of the Huron, Rouge, and Clinton rivers, Michigan.....	412
35. Upper Lake Plain section of Huron River Valley..... (after)	418
36. Upper Lake Plain-moraine section of River Rouge Valley..... (after)	418
37. Upper Lake Plain-moraine section of Clinton River Valley..... (after)	418
38. Map showing physiographic provinces of the Upper Peninsula of Michigan and location of Alger County, in which the Cambrian-Ozarkian contact occurs.....	422
39. Geological map showing hard rock formations of Alger County, Michigan..... (after)	422
40. General map showing location of the Herring Lake embayment, Benzie County, Michigan.....	438
41. Series of mid-bay bars between Upper and Lower Herring lakes.....	440
42. Dune area north of Lower Herring Lake.....	444
43. Dunes on bay-mouth bar north of North Bay Outlet.....	446
44. Dune area south of Lower Herring Lake.....	448
45. Dunes on bay-mouth bar south of North Bay Outlet.....	449
46. French electoral results in 1871, 1876, and 1877..... (after)	482

NOTES ON THE PREPARATION AND THE USES OF BASSWOOD FIBER BY THE IN- DIANS OF THE GREAT LAKES REGION

VOLNEY H. JONES

IN THE Great Lakes region in aboriginal times no plants were cultivated for their fiber and, apparently, no domestic animals were a source of fibrous materials. None of the important textile materials of the present day, such as cotton, flax, hemp, wool, and silk, were available to the Indians of this region. For cordage, thongs, and weaving materials they were dependent chiefly on the fibers, barks, and stems of wild plants and on some products from wild animals. The bast, or inner bark, of trees was one such source. The native materials are little employed at the present time. Commercial twine, cord, and yarn have almost entirely replaced them. However, many of the native products have been made within the memory of some of the older persons, and the techniques are still well known to them.

One source of material, the basswood tree (*Tilia americana* L. of the family Tiliaceae), is common in rich woods and fertile soil in the New England states and the Great Lakes region. Its range extends westward into the prairie region and southward to Virginia, Georgia, and eastern Texas. It is the only species of its genus in the Great Lakes region, but other species occur along the Atlantic Coast and in the southern states. The genus is represented by several species in the Eastern Hemisphere. It becomes a large tree, reaching a height of 60-70 feet or more, with a trunk diameter of 2-4 feet. It is generally considered to be a handsome tree and is much used as an ornamental plant. Other common names sometimes given in referring to this tree are American linden, lime tree, and whitewood.

There is so much confusion in the use of the terms "bast," "bark," "inner bark," and "fiber" that they no longer have any definite technical meaning. In botanical literature they have been replaced by more precise terms. In this paper the words are used

in the nontechnical sense. "Bast" refers to any fibrous tissue from the outer portion of a plant. The bast of the basswood tree which is utilized by Indians in the manufacture of cord is technically fibrous phloem tissue. "Bark" is generally used to refer to the tissues which are readily removed when a log is peeled, and thus to all tissues outside the cambium. The "outer bark" is the hard, dead, superficial layers of tissue, technically periderm and dead phloem, together known as rhytidome. "Inner bark" designates the living, active tissue next to the cambium, which is active phloem. Hence in the case of the basswood tree, "bast" and "inner bark" both refer to phloem tissue and are synonymous, but this would not be true of many plants in which the "bast" is of some tissue other than phloem. In common usage "fiber" may refer to any tough, strong, filamentous, organic substance. Botanically, a fiber is a particular type of cell, which may occur in almost any part of a plant. The "fiber" of the basswood tree used in cord manufacture is phloem tissue which contains fibers, but also vessels, companion cells, parenchyma, and sometimes other types of cells. The fibers are unusually numerous and give the tissue the strength which caused this tree to be selected as material for cordage.¹

While studying the methods of gathering and the utilization of plant materials by Indians of the Great Lakes region during the summer of 1933, I had the opportunity² to observe the gathering and preparation of the fiber of the basswood tree and the manufacture of this processed fiber into cord by Chippewa Indians of the Walpole Island Reserve in Ontario. Attention has frequently been called, briefly, to the utilization of fiber in this manner by various Indian tribes, but it seems desirable to record in some detail the manner of gathering, preparation, and use in this community, and to compare the processes as practiced there with those of other groups in the region.

These processes were demonstrated during early July, 1933, by Mrs. Hyman Smith, assisted by her husband, sister, and daughter. Mrs. Smith, who is reputed to be a full-blood Chippewa, appears to be about seventy years of age, but claims to be much older. According to her statements, she learned to prepare bark and to

¹ For a discussion of the technical and nontechnical usage of the words discussed above see Eames and McDaniels (3, pp. 56-57, 75, 213).

² As the Homeopathic Hospital Guild Scholar in Michigan Ethnology of the Graduate School of the University of Michigan.

weave mats by helping her mother and has done such work since her marriage, but not within the last twenty years.

The bark was gathered by Mr. Smith. Several basswood trees were growing in a woodlot near his house. He selected and cut three trees with smooth, straight trunks. They were about four, six, and ten inches in diameter. If trees are left standing, and bark is taken from only a part of the circumference, the wound may heal and the tree continue to grow. However, Mr. Smith wished to use the wood, and so cut the trees.

The bark at the base was loosened with the blade of an axe, grasped with the hands, and stripped from the trunk up to the lower limbs. It came off in strips about four inches wide and ten to fifteen feet in length (Pl. I, Fig. 1). These were rolled together to make carrying more convenient. According to Mr. Smith, bark can be stripped from the trees at any time of the year, but slips more easily during the summer months, when the sap is flowing. This is as would be expected.

The strips of bark were delivered to Mrs. Smith immediately, since they must be processed before drying. She took charge of the bark and began at once to separate the coarse outer bark from the softer inner bark. The strips of bark were doubled back on themselves, causing the rigid outer bark to break, after which it was pulled off in long pieces. That which adhered in spots was given individual attention, a knife being used when necessary. The inflexible part of the bark was finally completely removed by bending the strips and working them back and forth in a seesaw manner. The outer bark was discarded and the inner bark rolled into bundles and tied with small strips of the bark (Pl. I, Fig. 2; Pl. II, Fig. 2). It might be stored in this form for the future or be used immediately.

At the time the rolls of inner bark are to be utilized they are boiled in water, to which wood ashes have been added. When I saw the operations performed, a ten-gallon wash boiler was set on stones and about six gallons of water poured into it. A fire was built around the boiler and the water brought to a boil. About six quarts of ashes were then added. These were scooped from an ash pile, where ashes from the cookstove had been dumped. These ashes appeared to have been leached by rains and some were still damp. Mrs. Smith thought the ashes were mostly from oak wood, but believed that those from any wood would be satisfactory.

Immediately after the addition of the ashes, the bark was put into the boiler. The water ceased boiling momentarily, but soon began again. The rolls of bark were stirred and pushed under the water, which was agitated with a broom handle (Pl. I, Fig. 3). The water was kept at a boil.

When the boiling had continued for forty-five minutes one of the rolls of bark was removed and tested to ascertain whether it was beginning to separate into layers. Since it was found to be making little progress, the fire was built up, another gallon of ashes from the ash pile was added, and also about a quart taken directly from the stove. It was boiled vigorously for two hours more, after which it was again tested and was considered ready.

Cool water from the well was put into another boiler and the bark was transferred to it. The bark was rinsed thoroughly and then laid out on the grass to drain. Fresh water was obtained and the bark was rinsed again, after which the rolls were broken and the strips were hung across a clothesline to dry. When the bark was first placed in the lye solution it was almost white. After the boiling and rinsing it was a dark reddish brown.

After the strips of bark had dried for a while, but were still moist, they were taken from the clothesline. Some of the coarser outer layers of bark were removed and discarded. These were tough, but they were not woody. The remainder was then ready for use.

The bark was now worked back and forth briskly with the hands to loosen it, a process equivalent to the hackling of commercial fibers. It was soon loosened into layers of ribbon-like thinness, which were picked apart with the fingers. In this condition the bark may be used as a ready source of small wisps of twine for various uses; formerly a supply was always kept at hand. For purposes for which a stronger, more uniform product is required it is advantageous to twist the fiber into cords. In this process the thin layers of bark are split into half-inch widths and cut into lengths of about three feet. They are then ready for twisting.

While twisting the fibers Mrs. Smith sat on a chair, with her right knee crossed over her left. She pulled her apron tightly over her right knee, and tucked it under the knee so that it would stay in place. Two of the strips of bark — still slightly moist — were placed just above the knee (Pl. I, Fig. 4). They were kept about an inch apart, with the ends even. The ends were held with the fingers of

the left hand. The palm of the right hand, placed flat on the strips and pushed firmly forward, rolled the strips underneath it. Each strip of itself twisted into a firm single-strand cord. The operation was repeated two or three times. On the reverse motion the palm was lifted from the strands. After the two strands had been twisted separately for five or six inches, they were rolled outwardly in the manner described above, but on the return motion the palm was not lifted. The movement was suddenly reversed with a quick motion that rolled the strands together. The backward motion caused the strands to combine neatly and smoothly into a two-strand cord.

The farthest point at which the strands have been combined is now held with the left hand, the separate strips are placed side by side, and the process of rolling is repeated. After this the backward motion diminishes in importance. When the two strands are released with the left hand, the recoil from the outward rolling is almost sufficient to cause them to unite. The roll backward under the palm is continued, however, and assures that the combination takes place in a uniform and smooth manner. There is little tendency for the cord to unwind. On the outward motion the single strands are twisted clockwise, while on the backward motion the two strands are rolled together counterclockwise (Pl. II, Fig. 1). These opposite twists tend to counteract each other.

As the rolling is continued the loose ends are frequently combed with the fingers of the right hand to keep them straight and to prevent premature twisting. The reason for cutting the strips into short lengths is now apparent, since longer ones would twist and tangle. When the end of a strip is reached, splicing is accomplished simply by laying the end of a new strip over the end of the old one and rolling them together under the palm. The ends are lapped over for about an inch. The splicing is done so neatly that it is difficult to detect.

The bark must not be allowed to dry. A container of water is kept convenient. The hand is occasionally dampened and passed along the strands to moisten them. In rolling, the palm of the right hand is sometimes moistened. In splicing, moisture is particularly necessary, so that the ends of the strands usually are dampened by placing them in the mouth.

As the twine is completed it is rolled into balls about four to six inches in diameter (Pl. II, Fig. 1). These may be used immediately

or stored. The cord soon becomes dry and somewhat brittle and inflexible. Before being used it must be moistened to make it flexible again. Some of the cord which Mrs. Smith employed later in making a rush mat was prepared simply by submerging the ball of cord in a pan of water for about two minutes. It was then flexible and ready for use.

The rolling of twine is very slow. Mrs. Smith desired enough for the weaving of a rush mat and called in her sister to help. They had not made cord for years and doubtless had lost much of their skill, but they regained efficiency rapidly. It took them all day to make enough for the mat.

The gathering and preparation of basswood bark and the process of its manufacture into cord seem rather uniform throughout the Great Lakes region and follow essentially the methods described above for Walpole Island. However, the literature indicates that some variations exist. These will be noted briefly.

The trees selected by Mr. Smith were from four to ten inches in diameter. He considered that trees as much as one foot in diameter might be used, but that larger ones would be too tough and the bark too hard. Mrs. Smith disagreed with him on this point and said that only young saplings three or four inches in diameter were suitable, since the bark required less boiling and was easier to prepare. The Menomini use bark from "young sprouts of basswood" (4, p. 260). Three of four Indian tribes now or formerly in Wisconsin are reported as employing "saplings" and the other "young trees" (10, p. 76; 11, p. 269; 12, p. 422; 13, p. 114). It thus appears that the general custom was to utilize younger growth of sprouts, saplings, and smaller trees. This accounts for Mrs. Smith's discarding much of the coarser part of the inner bark.

In removing the bark from the tree Mr. Smith merely loosened it at the base and pulled it free with his hands, allowing the bark to come off in rough, uneven strips approximately four inches in width. It appears that more care is exercised elsewhere. The process among the Chippewa of Minnesota as described by Miss Densmore (1, p. 152) is as follows: ". . . an incision was made at a point as high as a man could reach, the cut descending straight to the ground, after which the bark was turned back in a sheet. It was then cut in lengthwise strips about 4 inches wide . . ." Hoffman, speaking of the Menomini of Wisconsin (4, p. 260), says simply

that the bark was removed "in sheets"; apparently this indicates the method described by Miss Densmore.

A minor variation in separating the outer bark from the inner may be noted. At Walpole Island the outer bark was broken and stripped off with the hands only. Skinner (9, p. 249) says that the fingers or, more often, the teeth were used. Smith gives this same procedure for the Menomini (10, p. 76), the Meskwaki (11, p. 269), the Ojibwe (12, p. 422), and the Forest Potawatomi (13, p. 114).

Mrs. Smith considers that boiling the bark in water to which ashes have been added is an essential operation and is convinced that the bark would not soften and separate properly without this treatment. At the Garden River Reserve, Ontario, however, I saw freshly prepared bark apparently of good quality. I did not see the process, but I was assured that ashes were not used in its preparation and that they were not at all necessary. I was informed that the fresh bark was placed merely in clear water and boiled "almost all day." Miss Densmore (1, pp. 152-153) describes the preparation of basswood bark by the Chippewa of Minnesota. The practice among them seems to be to remove the bark from the tree and to soak it in the water of a lake or a pond for about ten days and then to remove the outer bark. After this operation the inner bark may be used without further preparation, but that which is to be made into cord is later boiled, "if the cord is to be very strong," though the use of ashes is not mentioned. The soaking of the bark in a pond or a lake is similar to the method of retting flax as practiced in Europe.

According to Hoffman (4, p. 260) and Smith (10, p. 76), the Menomini of Wisconsin used ashes. Skinner (9, p. 249), speaking of the same group, indicates that they may or may not have boiled the bark in ashes. The Iroquois (8, p. 160) and the Meskwaki (11, p. 269) used ashes.

It seems reasonable that the lye of the ashes would be of value in counteracting the mucilaginous nature of the bark and that it would hasten the dissolving of the sap and the separation of the layers of bark. The use of ashes does appear to be the more common practice but, as noted above, the bark may be utilized after merely soaking in cold water, or after boiling in water without ashes.

The treatment of the bark after boiling and before being twisted into cord is varied. At Walpole Island hackling to soften and loosen

the fibers was accomplished by working it briskly with the hands. A more common practice is to fasten a scapula or a pelvic bone of a bear, deer, or other large mammal at some convenient place and to work the strips of bark back and forth through the natural aperture or groove of the bone. This method was not practiced and possibly was not known at Walpole Island. Miss Densmore describes it among the Chippewa of Wisconsin and gives an illustration (1, p. 153, and Pl. 59, Fig. a, facing p. 156). Hoffman reports this same practice by the Menomini (4, p. 260), but says that the scapula is used and that a hole about an inch in diameter is drilled in it. Skinner indicates that among the Menomini the practice is not uniformly as described by Hoffman. According to him, the bark may be "worked back and forth with the hands to break up the woody fibers and to detach them from one another." He states that "sometimes this is accomplished by rasping the cooked bark through the hole in the pelvic bone or crotch in the scapula of a deer or bear." The manner in which this operation is accomplished would seem to be a matter of convenience. Skinner (9, p. 251) explains that the finished cord is also rasped through the pelvic bone of a deer or a bear to make it even. I have found no account of this practice elsewhere.

The twisting of cord under the palm of the hand is apparently a fundamental and widespread practice. It accomplishes the same end as spinning with the spindle, and doubtless is a primitive forerunner of spinning. Fibrous material such as bast does not lend itself to the spindle as well as do such materials as cotton and wool, which have a natural crimp and more resiliency. However, flax, a bast fiber, is commonly spun with the spindle. Apparently, in aboriginal North America, spinning under the palm superseded spindle spinning, and in the regions where cotton, the spindle, and the true loom came in later, palm spinning still persisted as the technique preferred for some materials.

There is no mechanical reason why cord could not be rolled in the direction opposite to that customary with Mrs. Smith. If this were done the movement would take place toward the body in rolling the separate strands and away from the body in twisting them together. As a result the single strands would be rolled counterclockwise and the two twisted together in a clockwise direction. In fact, this method seems to be more common in other areas. Miner (7, p. 188), speaking of the Mississippi drainage area, says: "Left, or

clockwise, twisted cord appears universally in this region. Cave site No. 3 in the Norris Basin, Tennessee, a Woodland site, is unique in that it evidences the opposite twist as well. This uniformity of technique may be explained by the fact that practically all cording was done by rolling the fibers together on the thigh under the palm of the hand. The mechanical advantages of manipulating the strands with the right hand may well be responsible for the lack of differentiation." I must disagree with Miner in his assumption that clockwise twisting of cord is primarily a right-handed technique and in his implied corollary that counterclockwise twisting would be a left-handed technique. The cord which I saw manufactured at Walpole Island was certainly made with the right hand, and yet the direction was counterclockwise. Either direction of twist can be accomplished with either hand. Twisting involves rolling the cord away from the body and rolling it toward the body. The direction of the final twist depends on the choice of the operator in the order in which the movements occur. It seems that the habitual twist of cord in a particular direction is a culturally determined habit rather than one dictated by mechanical efficiency.

Unfortunately, most authors have been content to say only that the cord was rolled under the palm and have not specified the direction of the twist. Hoffman (4, p. 260) is an exception. According to his description, the strands are laid across the thigh and held with the left hand, and "the palm of the right hand is then rolled forward over both, so as to tightly twist the pair of strands, when they are permitted to unite and twist into a cord." The two strands rolled outward with the right hand would be twisted clockwise, and when they were "permitted to unite" would twist together in a counterclockwise direction. Thus counterclockwise cord is here again manufactured by a right-hand operation. The process is identical, therefore, with that which I observed, except that the backward motion of the hand is omitted and the strands are allowed to unite by the recoil of the outward roll. It seems possible that Hoffman may have overlooked this backward motion, since Skinner, writing of this same group later, says that the fiber was twisted into cord by sliding the palm "backward and forward" over the fibers until they twisted together. Smith (11, p. 269) describes the twisting of cord by the Meskwaki, who rolled it under the palm. The method is similar to that at Walpole Island, except that the strands are said to

be "twisted in opposite directions and allowed to run back together to make a two-ply cord." While it is difficult to understand how two strands could be conveniently rolled under the palm in opposite directions this may have been done. I am inclined to believe, however, that the Meskwaki practice followed the almost universal one as described above. Cord which when finished might be quite similar can, however, be manufactured in a different manner. Mason (6, p. 207) describes the Tlinkit Indians' method of making cord in which each of the strands is twisted separately and then both are twisted together, the entire operation being done with the fingers and palms of the hands.

In view of the lack of adequate descriptions of technique giving the manner of manufacture and the direction of twist, numerous ethnological and archaeological specimens in the Ethnobotanical Laboratory of the Museum of Anthropology of the University of Michigan were examined. Some few cords were braided, but the majority were twisted. In every case the strands were rolled in one direction and twisted together in the other. None were found with strands rolled in opposite directions, like those described by Smith. In appearance and nature they resemble cord from Walpole Island, and no doubt most of them were made in the same manner. The final twist is sometimes in one direction and sometimes in the other. The counterclockwise twist is not so rare as is indicated by Miner. It occurs in cord from each area examined, sometimes in the majority. Cord from western Texas cave sites shows about equal numbers of specimens with clockwise and counterclockwise final twist. Specimens from the Southwest, northern Mexico, and Ozark bluff dwellings have the counterclockwise in the majority. Material from the caves of Ohio and Kentucky contains a few counterclockwise cords, but those with clockwise twist are greatly in the majority.

While two-strand cord seems to be by far the most common type in the region under consideration, Morgan (8, p. 17) mentions three-strand rope as having been made by the Iroquois, but, unfortunately, does not describe the process. I have seen three-strand cord from the Ozark bluff dwellings in which the twist of the single strands is clockwise and that of the three twisted together counterclockwise. This indicates that the cord was very likely manufactured by rolling on the thigh under the palm of the hand, as described above, but it would not necessarily be so.

Both at Walpole Island and at Garden River Reserve the women began rolling the cord on the clothing over the thigh. At each place I stepped aside for a few minutes and returned to find them rolling the cord on the bare thigh. They were obviously quite embarrassed; they quickly covered their thighs and continued as before. Rolling on flesh would be easier than on clothing, which has a tendency to roll with the cord, and doubtless is the system universally followed when no strange males are around. The custom among the Chippewa of Minnesota, according to Miss Densmore (1, p. 153), was to roll the fiber "on the flesh of the right leg above the knee." Apparently modesty is on the increase among the Menomini. In 1895, when Hoffman made his observations (4, p. 260), the cord was rolled on the thigh, but both Skinner and Smith, who later saw the process, say that the rolling was done on the bare shin. At Peshawbestown, Michigan, two Ottawa women have a unique method of rolling twine. A piece of ducking about a foot long and several inches wide is tacked on a log about four feet long. The log is held between the knees and the cord rolled on the ducking, which has first been dampened. This method has the advantage of saving wear and tear on the thigh and at the same time preserves modesty.

It is fairly certain that in aboriginal times the gathering and preparation of textile materials as well as the spinning and weaving were the work of the women. At present it is difficult to gather information on the early division of labor. Apparently the adoption of European culture has caused a different division of labor. In almost every case I observed in two summers' work among the Chippewa and the Ottawa of Michigan and Ontario, the men gathered the materials or, at least, assisted. According to Skinner (9, p. 249), the Menomini women gather the basswood bark and manufacture the cord. Smith states that the gathering of basswood bark and its manufacture into cord is all done by the women among the Menomini, the Potawatomi, the Meskwaki, and the Ojibwe. Miss Densmore (1, p. 152) says the hackling of the bark was formerly performed by the children.

The uses of basswood fiber were quite numerous and varied. In its different stages, from the time when it was fresh from the tree until it was carefully boiled and twisted into cord, it was employed in a multitude of ways. In every well-regulated Indian household throughout the Great Lakes region balls of fiber and cord were kept available.

The fiber may be taken fresh from the tree, the outer bark removed, and the inner bark utilized without further preparation as thongs, lashings, or crude twine (9, pp. 248-249). The inner bark in its full thickness, without boiling, may be cut into strips and woven into bags and baskets (1, p. 152), but in most of the communities which I visited bark of the white cedar (*Thuja occidentalis*) was preferred for this and was used when available.

Miss Densmore (1, pp. 152-153) describes the preparation of "rice twine," the twine for tying together sheaves of wild rice. She states that the bark was soaked in a lake or a pond for about ten days. It was then removed and boiled, separated into layers, and cut into strips about one-half inch in width. These strips were tied together end to end without twisting. The twine made in this manner was rolled into a ball in such a way that it would unwind from the middle. Jenks (5, pp. 1058-1061) discusses the preparation and use of such twine and quotes several early sources to support his observations. His description concurs with Miss Densmore's in most particulars, but disagrees in saying that "green inner bark of basswood" was used rather than boiled bark.

Strips of boiled or fresh untwisted bark were utilized in many ways for tying and sewing. They were used to tie sinkers to fish nets, to bind packets, and to sew tops to bark and woven containers (1, p. 153). At the Garden River Reserve in Ontario I saw birch-bark containers for maple sap being manufactured. In this case boiled, untwisted basswood bark was the sewing material. Farther to the north and west spruce root is apparently more commonly used for this purpose.

Basswood bark found many uses in house construction. The pole framework was lashed together with fresh or dampened bark, which on drying and shrinking made a tight binding (1, pp. 22-28; 9, pp. 88-106; 12, pp. 422-423). The bark covering and cattail siding were sewed with strips of basswood fiber (1, p. 157; 9, pp. 88-106, 244). In addition, it was variously employed in binding and suspending objects.

The chief use of the twisted two-strand cord in various sizes was in the textile arts. That which I saw at Walpole Island later became the weft of a rush mat; that which I saw at Garden River was used as the border of a cedar-bark mat. It seems to be the customary material for this purpose throughout the region in question. It also

enters into many other textiles such as bags, burden straps, netting of snowshoes, and fish nets, and is employed in binding rims and in ornamentation of splint baskets and for many other purposes. The twisted cord would not be used for ordinary tying unless strength and permanence were desired. Generally a wisp of untwisted bark would serve as well.

In the Great Lakes region in aboriginal times basswood apparently was the chief source of fibrous material. It was a common tree; the fiber was readily available in quantity and, being strong and durable, was moderately easy to prepare for use. It was, however, not by any means the only plant used. Other trees or shrubs that furnished bark for fiber were two or three species of elm, particularly slippery elm (*Ulmus fulva*), white cedar (*Thuja occidentalis*), and moosewood or leatherwood (*Dirca palustris*). The uses and preparation of slippery elm and basswood seem almost identical, except that slippery elm requires no boiling and soaking (1, p. 152; 9, p. 249; 10, p. 77), but basswood seems to have been generally preferred. White cedar bark was sometimes a source of cordage, but more often was cut into strips from which mats and bags were woven. Leatherwood was more valued as a ready source of thongs than as a textile material, although it seems to have been used sometimes in preparing cord.

The fibers of several herbaceous plants such as Indian hemp (*Apocynum cannabinum*), swamp milkweed (*Asclepias incarnata*), and some members of the family Urticaceae, particularly nettle (*Urtica gracilis*), were used. The fiber of these plants is of a nature different from that of the woody plants, since it is chiefly from the pericycle and is extracted as almost pure fibrous tissue. It is finer and stronger than that of the woody plants and was used principally for better-grade cordage and textiles, whereas that of the woody plants was utilized in coarser textiles and as thongs. The disadvantage of the use of fibers of herbaceous plants was that the gathering and preparation were slower and more tedious. The twisting of the cord was generally done on the thigh under the palm, as in the case of the bast of trees.

Although basswood bark and other native fibers were of great importance to the Indians of the Great Lakes region they have been of little value to their white successors. They were used by the early settlers in the region, but fibers from the American tropics and from the Eastern Hemisphere have replaced them in commerce. Accord-

ing to Dodge (2, pp. 313-314), basswood fiber has found occasional use in America as material for rough cordage and coarse matting, and in Eurasia several species of basswood have been utilized, chiefly in Russia, Sweden, and Japan, as a source of material for rope, string, shoes, nets, mats, baskets, packing, paper, and other things. Though basswood may not be a commercially profitable fiber for use in normal times, it might, in an emergency, offer a ready substitute for such fibers as hemp, sisal hemp, and jute, the present supply of which is largely imported.

UNIVERSITY OF MICHIGAN

LITERATURE CITED

1. DENSMORE, F. 1929. Chippewa Customs. Bureau of American Ethnology, Bulletin Eighty-Six.
2. DODGE, C. R. 1897. A Descriptive Catalogue of Useful Fiber Plants of the World. United States Office of Fiber Investigations, Report 9.
3. EAMES, A. J., AND McDANIELS, L. H. 1925. An Introduction to Plant Anatomy. New York.
4. HOFFMAN, W. J. 1896. The Menomini Indians. Bureau of American Ethnology, Fourteenth Annual Report, Part 1, pp. 3-328.
5. JENKS, A. E. 1900. The Wild Rice Gatherers of the Upper Lakes. Bureau of American Ethnology, Nineteenth Annual Report, Part 2, pp. 1013-1137.
6. MASON, O. T. 1901. Twine-making without Apparatus. American Anthropologist, New Ser., 3: 207.
7. MINER, H. 1936. The Importance of Textiles in the Archaeology of the Eastern United States. American Antiquity, 1: 181-192.
8. MORGAN, L. H. 1904. League of the Ho-dé-no-sau-nee or Iroquois. Vol. 2. New York.
9. SKINNER, A. 1921. Material Culture of the Menomini. Indian Notes and Monographs, Museum of the American Indian, Heye Foundation.
10. SMITH, H. H. 1923. Ethnobotany of the Menomini Indians. Bulletin of the Public Museum of the City of Milwaukee, 4: 1-174.
11. ——— 1928. Ethnobotany of the Meskwaki Indians. *Ibid.*, 4: 175-326.
12. ——— 1932. Ethnobotany of the Ojibwe Indians. *Ibid.*, 4: 327-525.
13. ——— 1933. Ethnobotany of the Forest Potawatomi Indians. *Ibid.*, 7: 1-230.

PLATE I



FIG. 1



FIG. 2



FIG. 3



FIG. 4

- FIG. 1. Removing bark from basswood tree
FIG. 2. Rolling inner bark of basswood preparatory to boiling
FIG. 3. Boiling inner bark of basswood in lye water
FIG. 4. Twisting cord of basswood inner bark

PLATE II



FIG. 1. Ball of completed cord of basswood inner bark



FIG. 2. Roll of basswood inner bark prepared for boiling

NOTES ON INDIAN TRADE SILVER ORNAMENTS IN MICHIGAN

GEORGE I. QUIMBY, JR.

THIS study of Indian trade silver ornaments is based upon a detailed examination of two collections, one at the Kent Scientific Museum, Grand Rapids, and the other at the Museum of Anthropology, University of Michigan, Ann Arbor. These ornaments were excavated from Indian village sites and cemeteries of the historic period and from intrusive burials in prehistoric mounds. Occasional ornaments were surface finds.

There were selected for study 119 ornaments of the type commonly stamped with the identifying marks of the silversmiths who made them. Data on type of site and locale of find accompanied them. Characteristic of these ornaments were single- and double-barred crosses, crescent-shaped and circular gorgets, plain circular brooches, ornate circular brooches, star brooches, single-heart brooches, harp-shaped brooches, hair plates, arm bands, wristbands, bracelets, spoon locket, and animal effigies.

On 27 of these ornaments the touch marks were missing, owing mostly to breakage and corrosion, although a few seem to have been unmarked. But certainly 62 articles of silver, probably 75, were manufactured in Montreal by late eighteenth- and early nineteenth-century silversmiths. Since the area of distribution of ornaments upon which the marks are missing coincides with that of identified Canadian silver in Michigan, it might be valid to assume that at least half of this silver is also of Canadian manufacture, which would increase the total of Canadian ornaments to 89 (see Table I).

Of the ornaments remaining, one was manufactured in London and two were made in the United States. Fourteen bear touch marks which are unidentified. Thus it is apparent that at least half, if not considerably more, of the silver ornaments excavated from sites in Michigan are of British origin.

Although the brass and the copper crosses given to converts by

the Jesuits were church symbols, the silver crosses brought into the fur country at a later time by traders and government agents had little religious significance. Both the Florentine or double-barred cross and the Latin or single-barred cross were common trade items.

TABLE I
DISTRIBUTION OF ORNAMENTS BY COUNTY IN MICHIGAN

Mark	Emmet	Ionia	Kent	Lenawee	Mackinac	Marquette	Presque Isle	Unknown
R.C *.....	25	3	3	4	..	..	..	1
MONTREAL *	8	1	2	..	..	..	1	..
C.A *.....	5	..	..	1	..	2	..	1
P.H *.....	3	..	1	..	..	..	..	..
JH *.....	1	..	..	..	..	..	..	..
JO †.....	..	1	..	..	..	..	..	1
IS †.....	8	..	..	2	1	..	..	..
XIII.....	3	..	..	..	..	..	..	..
Lion passant...	2	..	..	..	..	..	..	..
AS (?).....	..	..	..	2	..	..	..	..
B.L, etc.....	1	..	..	..	..	..	..	..
CG.....	..	..	1	..	..	..	..	..
JD.....	1	..	..	..	..	..	..	..
JK.....	1	..	..	..	..	..	..	..
JT.....	1	..	..	..	..	..	..	..
P.J.D.....	1	..	..	..	..	..	..	..
P.J.D. BP.....	..	1	..	..	..	..	..	..
SH.....	1	..	..	..	..	..	..	..
W.....	1	..	..	..	..	..	..	..
WC.....	1	..	..	..	..	..	..	..
No marks.....	16	1	3	..	..	..	7	..
TOTALS	79	7	10	9	1	2	8	3

* Touch marks of Montreal silversmiths.

† Probably the touch mark of a Montreal silversmith.

The head and the foot of the shank, as well as the ends of the cross bars, were foliated. In all the double-barred crosses studied the lower crossbars were longer than the upper. Crosses of both types were pierced at the head to allow the insertion of a ring for suspension.

The crescent-shaped gorget is convex in cross section. The decoration occurs upon the convex side, and means for suspension are provided by bosses or buttons at the points of the crescent.

The circular gorget is a concave disk, with the ornamentation on the concave surface. Means for suspension are provided by two buttons or bosses on the upper part. Both the circular and the crescent-shaped gorgets were worn suspended from the neck by a band or a cord.

Hair plates appear as flat silver disks punched in various patterns, so that the perforations leave a tracery of geometric design enclosed within a circular rim. The whole ornament is approximately symmetrical. There are no means of attachment.

Plain circular brooches are convex disks with a central, circular opening or mouth. A hinged clasp or pin crosses this opening upon the convex side of the ornament, and this brooch, like all the others, is held in place on the garment by pulling a portion of the cloth through the opening, so that the hinged pin may be inserted. The tension of the cloth on the pin prevents the ornament from becoming unfastened.

The decoration, if there is any, appears on the convex side. The portion of the ornament from the mouth circumference to the rim is a solid surface and is not perforated.

The ornate circular brooch is similar to the plain circular brooch in that it also is a convex disk with a central opening or mouth, but, unlike it, is ornamented with a symmetrical arrangement in a circle of oval, triangular, diamond-shaped or crescent-shaped perforations. The decoration appears upon the convex side, and consists of various kinds of engraved lines on the solid parts of the brooch between the perforations. The rim may or may not be crenulated.

The harp-shaped brooch, of which there is only one among the collections studied, is similar in form to an Irish harp. It is perfectly flat, and bears no engraved decoration.

Heart-shaped brooches are in the form of a single heart, and generally are surmounted by a cross, a crown, or some other decorative form.

As their name indicates, star brooches are in the form of a star, although not necessarily a five-pointed one. They are slightly convex in cross section. The decoration, if present, appears upon the convex side. The various points of the star may or may not be enclosed within a rim.

Spoon lockets are spoon-shaped, with ovoid, flat covers. There is a ring for suspension at the base of the locket. Usually the covers

which are attached to the locket at the base by a hinge are the only decorated portions of the ornaments.

Arm bands are similar to bracelets, but are much wider in proportion to their length. Like the bracelets, they are not complete circles. Rather, there is a break between the ends of the band to allow for variation in the size of the arm or the leg, upon either of which they were worn. Longitudinal ridges are often present at the edges of the arm band. Decoration consists of stamped designs, engravings of animals, and geometric patterns.

Bracelets have longitudinal ridges, which are parallel to one another and run the entire width instead of being at either edge like arm bands. As a rule, the bracelets are not decorated with engraving or stamped design of any kind.

The only animal effigy represented among the Michigan collections is a bear. It is of silver and is hollow. The mouth has a ring for suspension. These various types are illustrated in Plate III.¹

The decoration upon the various types of silver ornaments consists of stamped or engraved design. A characteristic stamped design is illustrated by Figure 1 K. This type usually occurs at the margins of arm bands, just inside the longitudinal ridges at either side. Another type of stamped design is the small circle, which is similar to the design stamped upon pottery with a hollow reed. This is illustrated by Figure 1 J.

Engraved designs may be straight line, curvilinear, roulette, and rocker. The upper parts of Figure 1 L illustrate the rocker type, and the lower part is representative of the roulette type. These various types of engraving appear in any number of combinations and, in addition, may have spurs or dots associated with them.

A tentative identification of the possible totemic decorations, Figures 1 A-I, engraved upon these ornaments seems to indicate that they were owned by the Ojibwa or Chippewa, the Ottawa, and the Potawatomi Indians. These Indians were British allies; thus it is not surprising that so large a proportion of Canadian silver should be found in this region.

At the beginning of the war between the United States and England in 1776 both the Americans and the British made great efforts to secure the support of the Indians. Nevertheless the Indians in

¹ For more detailed explanation and description of types of silver ornaments see Beauchamp (1).

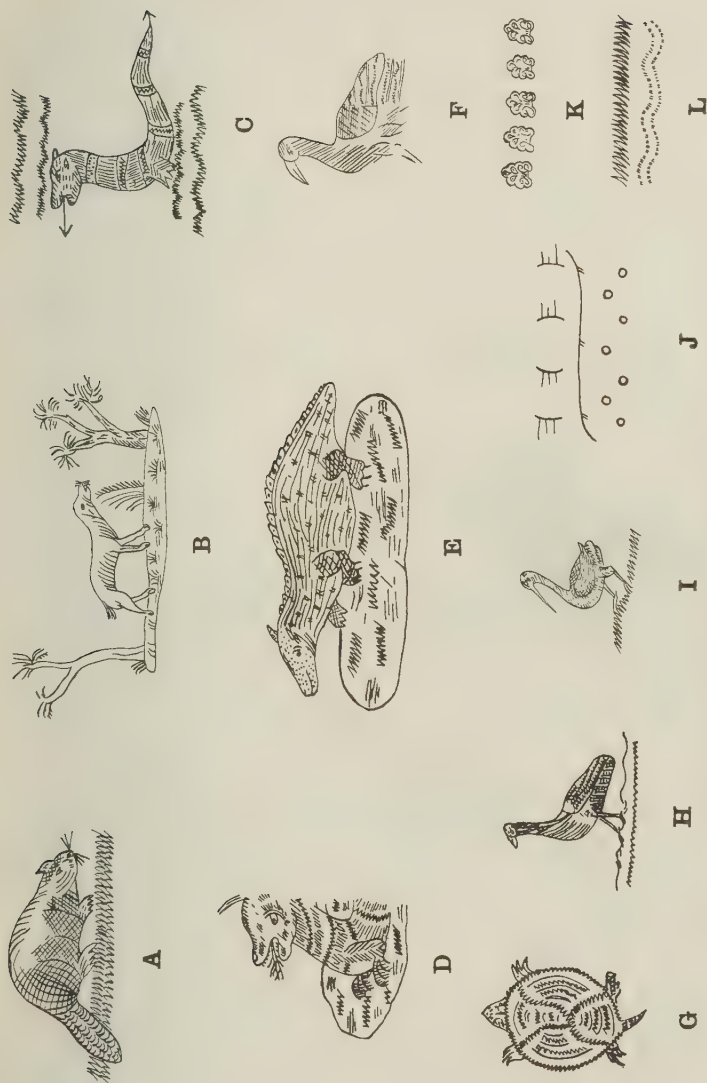


FIG. 1. Design elements and pictures engraved upon Indian silver ornaments

general favored the British, perhaps because of the active work of their agents in distributing presents among them. So thorough were the efforts of these agents and traders that the influence of the English lasted until after the War of 1812.

In Volume 10 of the Knox Papers, which are in the Clements Library at the University of Michigan, there is a communication from Captain Knox to General Haldimand dated April 7, 1781. Included in the presents for Indians at Niagara were the following ornaments:²

- 50 large silver Medals with the King's Bust on one side, the other arms.
- 100 smaller ditto — on one side the king's bust; the other Lion, Wolf, Si^a
- 500 Silver arm bands with King's arms and supporters, Si^a engraved on them.
- 500 Wrist bands
- 100 Silver Gorgets engraved with the King's arms and supporters Si^a
- 1000 Silver shirt buckles (brooches) sorted.
- 500 pairs Silver earrings with drops, sorted.

In the *Michigan Pioneer and Historical Collections*, 15: 606-607, there is a "Recapitulation of Indian Presents &c shipped for the Post of Michilimackinac in the Brigade of Canoes which Left Lachine (Montreal) the 9th of July 1814 in charge of Capt. J. M. LaMothe & Consigned to Lieut. Col. McDonall." Among a considerable variety of trade goods and supplies these articles of silver are found:

- 5000 Ear Bobs
- 60 Pairs Arm Bands
- 3640 Common Silver Broaches [probably miniature round brooches]
- 50 Silver gorgets

An "Invoice of Sundry Indian Stores delivered (to) Robert Dickson Esqr. Agent & Superintendent of the Western Nations by order of Lieut. Coln. McDonall Comdg Michilimackinac," signed "Jno Askin, Indian Department Michilimackinac 29th Octr. 1814" appears on page 655 of the volume already cited. The silver ornaments which are listed therein are:

- 30 Pairs of Arm Bands
- 1874 Brooches
- 1250 Pairs of Ear Bobs
- 40 Gorgets

Thus on the basis of the documentary evidence it is apparent that the British were presenting and trading silver ornaments in the

² The list is reproduced here as it occurs in the original.

Great Lakes region and in Michigan during the period from 1776 to 1814.

Further evidence that the silver ornaments studied belong to this period is brought out by the identification of the touch marks and the makers.

In some regions the Indians themselves took over the art of silversmithing after it had been introduced into their territories by white men.³ The Iroquois of New York are a notable example of this. But from the appearance of the ornaments and the fact that most of them bear touch marks, it does not seem that the Indians of this region manufactured much of the silver found here.

Robert Cruickshanks of Montreal was the ranking silversmith with regard to quantity of production for the fur trade in Michigan and vicinity. His touch mark, the script letters 'R.C' enclosed in a curvilinear cartouche, appears upon 36 of the 119 ornaments. After learning his trade in London Cruickshanks⁴ emigrated to Boston about 1768, where he worked as a silversmith. According to the accounts of Colonel Daniel Claus, silver ornaments were supplied for the Indians by Cruickshanks in 1779. (He should not be confused with the Robert Cruickshanks of London who completed his apprenticeship to Alexander Johnson in 1776 and worked in that city until 1806 or later.)

Being a Loyalist, Cruickshanks fled to Montreal in the opening years of the American Revolution and is there listed as a merchant in 1781. For a while he was in partnership with Charles Arnoldi, but this was terminated in October, 1784. In the records of the Church of Lacadie Cruickshanks' name appears under the dates 1787, 1788, and 1789. The Government House in Montreal bought cutlery of Cruickshanks in 1789. Robert Cruickshanks died suddenly on board the ship *Eweietta* on April 16, 1809, at Spithead.

³ Harrington (2) and Parker (5).

⁴ This and subsequent tentative identifications, unless otherwise stated, were made by means of rough sketches of the touch marks sent to various scholars, who communicated their opinions to me by letter. For the identification of the touch mark and for the information concerning Cruickshanks I am indebted to the historian E. Alfred Jones, London, England; Professor Ramsay Traquair, head of the School of Architecture, McGill University, Montreal; Dr. Amos W. Butler, Indianapolis, Indiana; E. Z. Massicotte, archivist, Old Court House, Montreal; Dr. James F. Kenney, acting dominion archivist, Ottawa; John Marshall Phillips, Gallery of Fine Arts, Yale University, New Haven, Connecticut.

Another Montreal silversmith, Charles Arnoldi,⁵ a onetime partner of Cruickshanks, is probably responsible for eight of the ornaments studied. His touch mark consisted of the script letters 'C.A' in a curvilinear cartouche. Records pertaining to him are dated 1784, 1788, and 1810. At the last date he was established at 16 Notre Dame Street in Montreal. In his later years he was associated with a silversmith named Comens.

There is a possibility that the touch mark consisting of the Roman capitals 'P.H' in an oblong cartouche is that of Henri Polonceau,⁶ a silversmith of Laprairie, who entered business in Montreal in 1806. However, the reversal of the initials in the touch mark is entirely without precedent. The last known record of Polonceau is dated 1810. In the two collections there are four ornaments with this mark.

Although the silversmith who used the Roman capitals 'IS' in a square cartouche is unknown, evidence of his work is found in Canada. In the Bishop's Palace at Quebec there is nineteenth-century silver cutlery which bears this mark.⁷ This fact and the comparatively high percentage of silver ornaments bearing 'IS' in the collections studied might lead one to conjecture a Canadian origin for it.

Two of the ornaments in the collections studied bear the Roman capitals 'JO' in a square cartouche. This touch mark is probably that of John Oaks,⁸ a Montreal silversmith and onetime associate of Charles Arnoldi.

One ornament, a silver gorget incised with the Royal Arms of England, was manufactured in 1781 by Benjamin Laver, Bond Street, London. The marks on it are: (1) 'B.L,' in thick letters, in an oblong cartouche; (2) the small letter 'f' in a square cartouche; (3) a lion passant in an oblong cartouche; and (4) a crowned leopard in a shield-shaped cartouche.⁹

Upon a harp-shaped brooch from Emmet County appears the mark of an unknown Montreal silversmith. It consists of the script letters 'JH' in a curvilinear cartouche, which in addition is stamped "Montreal" in small Roman capitals.

⁵ The information concerning Arnoldi was supplied by Professor Ramsay Traquair and Mr. E. Z. Massicotte.

⁶ According to Professor Ramsay Traquair.

⁷ According to Professor Ramsay Traquair.

⁸ According to E. Z. Massicotte. ⁹ Identified in *Old London Silver* (4).

Twelve varied ornaments are merely stamped with the word "Montreal," in small Roman capitals. These pieces bear no other mark.

Only two of the 119 ornaments bear touch marks of United States silversmiths; one was manufactured by either John David, Jr., or John Dupuy, both of Philadelphia, and the other by John Kinzie of Michigan. The David, Jr., or Dupuy mark ¹⁰ consists of the capitals 'JD' in an oblong cartouche. Since the mark of John David, Jr., is known to appear in an oval cartouche, it is more likely that the one in question is that of Dupuy, who was working in Philadelphia from 1769 to 1803. This mark is stamped upon a double-barred cross. John Kinzie's mark,¹¹ consisting of the script letters 'JK' in an oblong cartouche, is stamped upon a large double-barred cross from Emmet County. Kinzie, who received his training as a silversmith in Montreal, was working in the Michigan region from about 1800 to 1815 or later.

The touch marks of unknown silversmiths which appear upon Indian silver ornaments in Michigan are as follows: the Roman numerals 'XIII' in an oblong cartouche, on three objects; the Roman capitals 'AS' in an oblong cartouche, on two; 'CG' in a square cartouche, on one cross; a lion passant in an oblong cartouche, on two bracelets; 'JT' in an oblong cartouche, on one brooch. Other unknown marks are: 'P.J.D.' in an oblong cartouche with serrated edges; the same letters in an oblong cartouche with straight edges and accompanied by the stamped letters 'BP' in a square cartouche; and the letter 'W' in an oblong cartouche. The initials 'BP' in the square cartouche might be the mark of Benjamin Price of Philadelphia, although it is certainly incongruous to find them on the same ornament with another touch mark. One gorget is stamped with the Roman capitals 'SH' in an oblong cartouche and one brooch is marked with the script letters 'WC,' or possibly 'JM,' in an oblong cartouche.

SUMMARY

On the basis of the touch marks identified and of documentary evidence, it would seem that Indian silver ornaments were brought

¹⁰ According to Harrold E. Gillingham, Germantown, Philadelphia, and John Marshall Phillips.

¹¹ According to John Marshall Phillips.

into Michigan during the period from the American Revolution to the War of 1812. More than half are British in origin; a large number came from Montreal, most of which were made by Robert Cruickshanks. In some places the Indians took over the art of silversmithing, but the Indians of this region do not seem to have done so, although they may be responsible for some of the decoration.

Possible archaeological applications of the study of trade silver are the dating of historic sites and the identification of the tribe which occupied a given site and of the peoples on the basis of their governmental affiliations as revealed by the silver.

UNIVERSITY OF MICHIGAN

BIBLIOGRAPHY

1. BEAUCHAMP, DR. W. M. *Metallic Ornaments of the New York Indians.* Bulletin of the New York State Museum, No. 73. Albany, New York, 1903.
2. HARRINGTON, M. R. *Iroquois Silverwork.* Anthropological Papers of the American Museum of Natural History, Vol. I, Part 6. New York, 1908.
3. *Knox Papers*, Vol. 10. Clements Library, Ann Arbor, Michigan. (All these papers are in manuscript.)
4. MONTAGUE, HOWARD. *Old London Silver, Its History, Its Makers, and Its Marks.* Chas. Scribner's Sons, New York, 1903.
5. PARKER, ARTHUR C. *Origin of Iroquois Silversmithing.* American Anthropologist, New Ser., Vol. 12, No. 3. Lancaster, Pennsylvania, 1910.
6. *Copies of Papers on File in the Dominion Archives at Ottawa, Canada, pertaining to the Relations of the British Government with the United States during the Period of the War of 1812.* Michigan Pioneer and Historical Collections, Vol. 15. Lansing, Michigan, 1909.

PLATE III



FIG. 1. From top to bottom: Row 1, large circular gorget, small circular gorget, hair plate; Row 2, double-barred cross, single-barred cross; Row 3, large crescent-shaped gorget, small crescent-shaped gorget, hair plate

FIG. 2. From top to bottom: Row 1, large double-barred cross, circular ornate brooch; Row 2, plain circular brooch, small circular brooch, turtle or spoon locket, small heart brooch, harp brooch; Row 3, star brooch, star brooch, large heart brooch, large star brooch

MINIMUM INTENSITY OF ARTIFICIAL ILLUMINATION EFFECTIVE IN SUPPLEMENTING THE NORMAL PHOTOPERIOD *

J. PERRY AUSTIN

IN ORDER to determine how low the intensity of artificial illumination could be and still be effective in supplementing the normal winter photoperiod, the following experiment was conducted in a long section of the greenhouse at the University of Michigan Botanical Gardens during the winter of 1933. The temperature of this part of the greenhouse was 55° to 65° F. during the day, and 50° to 55° F. at night. The normal winter photoperiod was supplemented by light from a 500-watt tungsten-filament Mazda lamp suspended at one end of the greenhouse and provided with a reflector tilted to one side to direct the light along the length of the greenhouse. This gave supplementary light ranging in intensity from 56 foot-candles at one end of the greenhouse to less than 0.2 foot-candle at the other. The light was turned on one-half hour before sunset and was turned off late at night, at the proper time to give a total light period of 20 hours.

Rudbeckia bicolor superba (a long-day plant) and *Cosmos sulphureus* (a short-day plant) were subjected to these conditions. Groups of plants of the two species were placed at various distances from the source of light. The intensity of artificial illumination reaching each group, as measured by the MacBeth Illuminometer, is tabulated below. For each group the intensity at the near and the far side of the group, with reference to the light source, was measured at the beginning and the end of the period during which the experiment was conducted.

At the end of twenty-one weeks all the *Cosmos* plants of groups 4 and 5 had developed flower buds, and three of these plants were flowering; none of those in groups 1, 2, and 3 showed any indications

* Papers from the Department of Botany of the University of Michigan, No. 581.

of budding. The *Rudbeckia* plants in groups 1, 2, and 3 developed stems, budded, and flowered. Flower buds appeared on the plants in group 2 at about the same time as in group 1 (average age at budding approximately twelve weeks), but budding was delayed

TABLE I
LIGHT INTENSITY IN FOOT-CANDLES

Group	Beginning of experiment	End of experiment	Number of plants	
			Rud.	Cos.
1	56.0 to 42.6	37.4 to 25.4	19	17
2	9.0 to 8.1	6.2 to 4.7	9	9
3	1.96 to 1.78	1.58 to 1.36	16	13
4	0.395 to 0.388	0.27 to 0.23	13	11
5	0.260 to 0.246	0.19	14	14

about three weeks in group 3. In groups 4 and 5 there were no indications of stem elongation until the last of March, when the length of the normal photoperiod had become equal to the critical photoperiod for stem elongation in *Rudbeckia*.

Under the conditions of this experiment the critical intensity (intensity necessary to supplement the normal photoperiod effectively) for both *Cosmos sulphureus* and *Rudbeckia bicolor superba* lies between 0.4 and 1.8 foot-candles.

UNIVERSITY OF MICHIGAN

ANATOMY OF THE LEAF TRANSITION REGION OF *URGINEA MARITIMA* *

DOROTHY CHAPMAN CARPENTER

INTRODUCTION

URGINEA MARITIMA, or sea onion, is a member of the Liliaceae and is found at certain points along the shores of the Mediterranean Sea. It has a large bulb, at the base of which is a meristematic region which gives rise above to leaves and bulb, and below to roots. As the leaves first appear from the top center of the bulb they are round and solid. Later — the amount of previous growth is variable with different leaves — a split in the solid round structure occurs, making it flat in all future growth.

According to extensive anatomical work completed by Agnes Arber (1-3) and her phyllode theory, on comparative morphological and ontogenetical grounds such leaves among the Liliaceae, including those of the near relative of Urginea, Scilla, are equivalent to leaf bases. The solid tips are held to represent the last rudimentary phase of the disappearing petiole, and the lamina is entirely absent. In *Urginea maritima*, as in *Iris xiphioides* and others, the cylindrical petiolar limb may be of considerable length, or may be reduced very greatly, so that the leaf consists almost entirely of sheath, with the vestigial petiole forming merely the cylindrical apex. Solid tips have been observed anywhere from 6 to 17 cm. in length before the flat region begins. In other liliaceous forms such as *Hyacinthus* this relation has become fixed, with the chief part of the leaf of leaf-sheath nature, the petiole being only a solid tip.

The change from round to entirely flat takes place in a narrow zone of not more than 8 to 15 mm. in extent, and it is the structural transitions in this region that are described in this paper. Figure 1 of Plate IV is a general diagram of the entire leaf, showing between the numbers 10 and 28 the area of change. The tissue was killed in weak chromoacetic acid solution, since it was found that with such

* Papers from the Department of Botany of the University of Michigan, No. 565.

succulent, watery material anything stronger caused great shrinkage. It was run through a butyl alcohol series, embedded in paraffin; serial sections 10 mm. in thickness were cut from top to bottom, mounted, and stained with safranin and anilin blue.

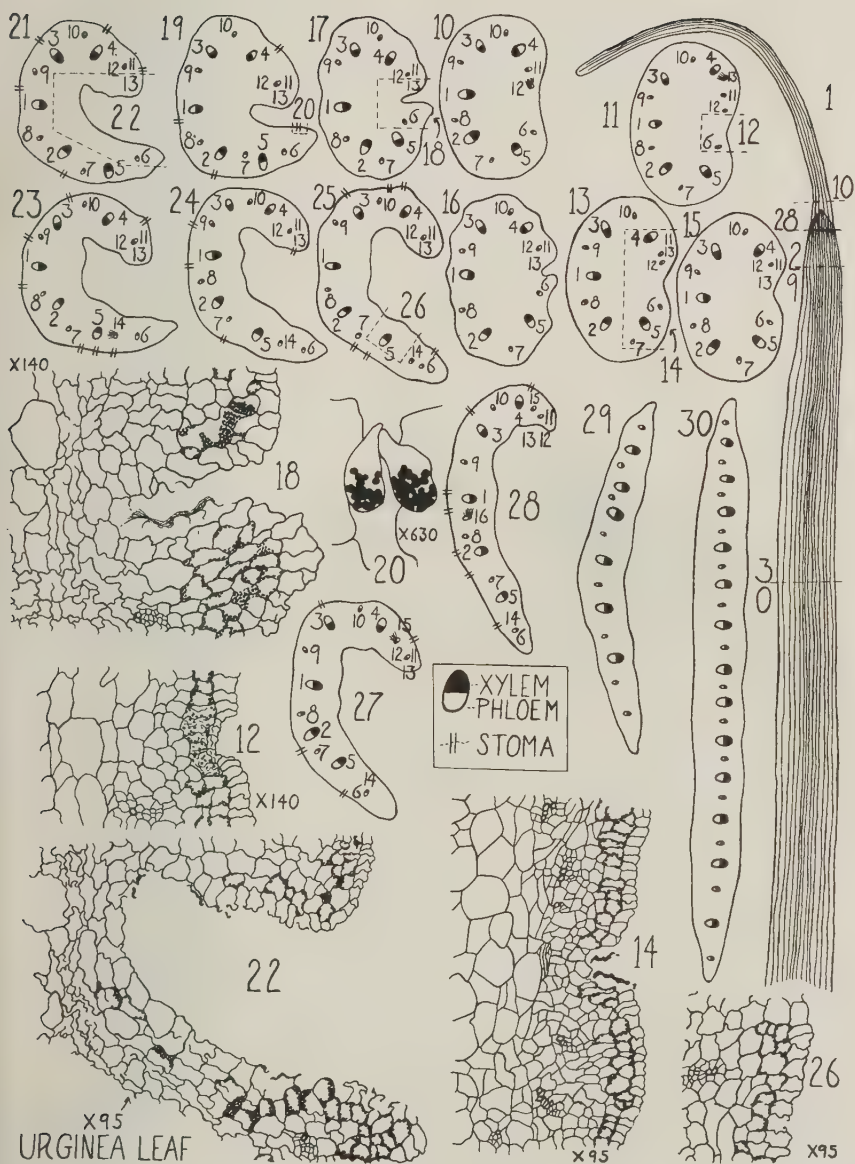
The leaf epidermis is thin-walled, noncutinized, and contains in the flattened regions numerous stomata. The guard cells are also thin-walled and open into air spaces. They are found on both upper and lower surfaces. The majority of leaf tissue is cortical, being composed of large parenchyma cells in the center regions and smaller parenchyma cells in the outer ones. The first layer beneath the epidermis, although no different in shape or size, contains chloroplasts. The vascular bundles are collateral with the endarch xylem innermost and are arranged in a ring within the solid leaf tip. At the completion of the split the leaf is flat and thin, with the bundles centered the width of the leaf in a straight line. The greater part of the tissue at this stage is still cortical, but there is a row of chlorophyll-bearing cells directly beneath both upper and lower epidermal surfaces (4).

DESCRIPTION

Figure 10, a cross section of the leaf tip, shows an oval shape somewhat flattened on one side. There are five large vascular bundles, numbered 1 to 5 on the plate, and seven small bundles alternating with the large ones, numbered 6 to 12. Bundle 12 is in the process of being formed, laterally, from bundle 11. At a slightly lower level in the leaf (Fig. 11) a new small bundle, number 13, arises laterally from number 4 and the splitting of the leaf begins on the flat side as a shallow indentation between bundles 12 and 6. This latter split begins by the shrinking of four or five epidermal cells to about one half of their natural length and by their collapsing inward upon the chlorenchyma cells just beneath them. The walls between these chlorophyll-bearing cells partially break down, allowing the contents to run together (Fig. 12).

Still lower in the leaf, bundle 13 bends laterally, combining with bundle 11, and bundle 12 curves slightly toward them (Fig. 13). The indentation becomes deeper, and a definite splitting region is visible where the epidermis and the chlorophyll-bearing cells have entirely broken down. Remnants of their cell walls and contents still exist, but are unattached. Four or five rows of cells inward,

PLATE IV



Transition region of the Urginea leaf

and directly opposite the indentation, a region of compression begins at right angles to the split. At first it consists of but four or five cells whose side walls are being pushed together (Fig. 14).

Farther down, bundle 12 continues its curve and joins bundle 11-13 (Fig. 15). The entire leaf becomes extremely shrunken, with its exterior scalloped, and the indentation is deeper (Fig. 16). The region of compression now covers an area of 12 to 15 by 6 to 8 cells. The large central parenchyma cells also show shrinkage. The split increases as more of the central cells break down, and its outermost walls are now composed of what were previously inner cortical cells. No chlorophyll-bearing cells remain in the region of the split; they are confined to the two "lips" of the indentation (Figs. 17-18).

In Figure 19 the split is now so deep that the leaf edges are beginning to turn away from each other. The outer surface is straightening out, and there are fewer scallops in it. The cells inside the leaf are still greatly shrunken. Stomata and guard cells appear for the first time on the epidermis of the newer split surface. They open into air spaces, and the guard cells are thin-walled (Fig. 20). The split increases in size rapidly. The epidermis covering the outside of the leaf is greatly shrunken, and in many places its cell walls are partly torn and ragged. One "lip" or side of the leaf straightens out much faster than the other. The inner parenchyma cells continue to break down as the split increases, and those immediately bordering on the indentation have become almost uniform in size. There is still a very definitely compressed area in the leaf center, but it is narrower. A row of chlorophyll-bearing cells is beginning to form along the split region, being found first at the two "lips" and extending inward for 6 to 9 cells. There are also several scattered chlorophyll cells nearer the central part of the split (Figs. 21-22).

In Figure 23 a new small bundle, number 14, is given off from number 5. A secondary indentation occurs in the already split surface, allowing the leaf side, which is slower in straightening, to swing out more rapidly. The broken cortical cell walls are clearly visible. The compressed area has almost disappeared, but the central cells are still shrunken. The entire leaf becomes thinner, with the sides straightening rapidly (Figs. 24-25). Chlorophyll has appeared in a single layer of cells along the split area a third of the way from each side. The shrinkage in the central cells is gone, and the cell walls are again rounded out (Fig. 26).

Farther down, a new small bundle, number 15, arises from number 4, and bundle 14 curves laterally and unites with number 6. There are still but a few scattered chlorophyll cells along the very center of the split. The sides continue to straighten, and the vascular bundles become centered in the leaf width (Fig. 27). The leaf is nearly flat, with but one side still crooked over. The line of chlorophyll-bearing cells, except for the very central region, is now completely along the split surface. There is no cell shrinkage in the leaf center or the straightened side, and but a very little in the crook. A new bundle, number 16, is formed from bundle 1, making 5 large and 8 small bundles, or a total of 13, in the region where the serial sections were discontinued (Fig. 28).

About 1 cm. below the splitting region a few transverse sections were made; 6 large bundles and 8 small ones are found. The chlorophyll-bearing cells form a complete layer, one cell thick, along the newly formed surface. The epidermal cells on the newer side, composed of the previously internal cortical tissue, are still much larger than those on the older surface. All the leaf at that point is almost flat (Fig. 29). Sections taken from 7 cm. below this region and throughout the rest of the basal leaf portion show a general anatomy similar to one another. There are 13 large bundles, with 14 small alternating ones. The two epidermal layers are the same size, and the sides of the leaf are entirely straightened (Fig. 30).

SUMMARY

1. An *Urginea maritima* leaf is solid and round at the tip and flat and ribbonlike throughout the basal portion.
2. The distance of the region of splitting from the tip of the leaf varies greatly with individual leaves.
3. The split is lysigenous rather than schizogenous and extends from one epidermis into the parenchymatous interior of the leaf.
4. The sides formed by the split swing out, and the entire leaf thins transversely and elongates.
5. Just before the splitting commences the leaf has 5 large vascular bundles and 6 small alternating ones. Where the split is completed, there are 5 large and 8 small bundles. The entire basal portion, from 7 cm. below the split, has 13 large and 14 small alternating bundles.

6. The vascular bundles are collateral with the endarch xylem innermost.

7. The epidermal cells on the newly split surface of the leaf are formed from previously internal parenchyma cells.

UNIVERSITY OF MICHIGAN

LITERATURE CITED

1. ARBER, AGNES. 1918. The Phyllode Theory of the Monocotyledonous Leaf with Special Reference to Anatomical Evidence. *Ann. Bot.*, 32: 465-501.
2. ——— 1920. Leaf Base Phyllodes among the Liliaceae. *Bot. Gaz.*, 69: 337-340.
3. ——— 1922. On Leaf-Tips of Certain Monocots. *Linn. Soc. Journ. Bot.*, 45: 467-476.
4. EAMES, A. J., AND MACDANIELS, L. H. 1925. *Introduction to Plant Anatomy*. McGraw-Hill Book Co., New York.

VEGETATION OF THE PORCUPINE MOUNTAINS, NORTHERN MICHIGAN

PART II. FLORISTICS

HENRY TOWNSEND DARLINGTON

A DESCRIPTION of the region of the Porcupine Mountains, including location, physiography, climate, and some statement of early biological work, appears in Part I (4) which is devoted to the ecology of the area. A somewhat more specific account of early botanical work in the area will now be given. As early as 1845 Wm. A. Burt, a land surveyor, working in coöperation with C. T. Jackson, United States geologist for the mineral lands of Michigan, made a township-line survey over an area including the Porcupine Mountains. Though not a botanist, he took the opportunity of collecting plants on his various expeditions. In a report on the geology of the region Jackson (5) includes a "catalogue of the plants collected by Wm. A. Burt, Esq., in the primitive region south of Lake Superior in 1846." The plants were collected between lat. $45^{\circ}53'$ and $46^{\circ}45'$ N. and were identified by Dr. Dennis Cooley, a pioneer botanist of the state. The catalogue "embraces such plants as may be found in many parts of the survey, and most of them in nearly every township." This list, which includes 169 vascular plants, has been ascribed to the Porcupine Mountains, but the survey covered a much larger area, and township designations given for each species show that the plants were mostly collected south of the Porcupines.

Some account of the biological expedition sent out by the University of Michigan in 1904 was given in Part I. The report of this expedition (7) contains descriptions of the habitats of the various biota observed. Many of the commoner species of plants, especially those of ecological importance, are mentioned. Dr. Ruthven listed seventy-eight species of vascular plants and thirteen of lichens.

During a part of the summer of 1922 the writer spent some weeks making an ecological survey of the mountains, and in the following summer revisited the region, accompanied by Dr. E. A. Bessey of

Michigan State College, during which time additional specimens were collected. Nearly the entire month of August was spent in studying the vegetation and also in the exploration of some localities not visited the previous summer. On account of the lack of roads and trails and the very rough topography the major part of the collecting was done in the general region around Carp Lake, close to which headquarters were established in a deserted mining cabin. Carp Lake is merely a broadened portion of Carp River, which flows in a general southwesterly direction, emptying into Lake Superior.

Opportunity was found to explore the upper reaches of this river, to follow it to the Lake Superior shore, to investigate the vegetation around Little Carp Lake and the mouth of Little Carp River, to visit Government Peak, the highest point of the region, and to examine the shore of Lake Superior from Union Bay west for several miles.

The main range of hills (referred to in this paper as the "ridge" or the "range") lies just north of Carp Lake, nearly paralleling the Lake Superior shore line for a distance of at least 10 kilometers. The area between this range and the shore, as well as that to the south, is covered with a climax forest of hemlock and sugar maple.

Many types of habitat may be found within the area studied. Some of the most interesting are those at or near the top of the cliffs bordering the range and on the broad talus areas on the north side of the escarpments. The forested region was much more easily examined, as was also the Lake Superior shore from Union Bay west. On account of its accessibility the valley of Carp River was given much more attention than that of any other stream.

It is realized that the appended list of plants is not complete, especially for the entire area included within the range of the Porcupine Mountains. It is believed, however, that it represents a fairly accurate cross section of the vegetation of the region. The nomenclature follows that of *Gray's Manual*, Seventh Edition, except in the case of certain species for which research has shown that the older names are invalid. The writer has taken a conservative attitude in regard to the adoption of names given to segregates of well-established species.

Certain species are included which were reported by Ruthven in 1904 and by Dr. Norman Fassett, of the University of Wisconsin, in 1929. These have not been seen by the writer. The species of

Rubus collected were named or verified by Dr. L. H. Bailey, of Ithaca, New York; those of Equisetum, by Dr. J. H. Schaffner, of Ohio State University.

The second summer's work was made possible by funds provided by the Michigan Geological and Biological Survey. The writer wishes to express his appreciation of the aid rendered by Dr. A. G. Ruthven, at that time chief naturalist of the Survey and director of the Museum of Zoölogy of the University of Michigan.

PTERIDOPHYTA (FERNS AND FERN ALLIES)

1. OPHIOGLOSSACEAE (Adder's-Tongue Family)

BOTRYCHIUM MATRICARIAEFOLIUM A. Br. (*B. ramosum* of Gray's *Manual*). — Grape fern. Occasional in moist woods.

BOTRYCHIUM TERNATUM (Thunb.) Sw. var. INTERMEDIUM D. C. Eaton. — One specimen in open woodland.

BOTRYCHIUM VIRGINIANUM (L.) Sw. — Rattlesnake fern. Frequent in moist maple woods.

2. OSMUNDACEAE (Flowering-Fern Family)

OSMUNDA REGALIS L. var. SPECTABILIS (Willd.) Gray (*Osmunda regalis* of authors. See *Rhodora*, 21:176. 1919). — American royal fern. Common.

OSMUNDA CLAYTONIANA L. — Low ground; frequent along Carp River; the commonest species.

OSMUNDA CINNAMOMEA L. — Cinnamon fern. Low ground.

3. POLYPODIACEAE (Fern Family)

WOODSIA ILVENSIS (L.) R. Br. — Common on bluffs of the main range.

WOODSIA CATHCARTIANA Robinson. — Plants agreeing more or less closely with the description given for this species are very common in the Porcupine Mountains. However, forms occur which have exactly the habit of *W. oregana*. Specimens were sent to Dr. C. A. Weatherby of the Gray Herbarium who, after carefully comparing them with *W. oregana* from other sections, is inclined to believe that *W. Cathcartiana* may eventually prove to be a localized variety of the former species. Dr. N. C. Fassett found specimens of this group in which the spores were abortive.

- CYSTOPTERIS BULBIFERA (L.) Bernh. — Bladder fern. Upper reaches of Carp River.
- CYSTOPTERIS FRAGILIS (L.) Bernh. — On shaded rocks; frequent.
- PTERETIS NODULOSA (Michx.) Nieuwl. (*Onoclea Struthiopteris* of authors). — Ostrich fern. Moist ground; frequent.
- ONOCLEA SENSIBILIS L. — Sensitive fern. Low ground; common.
- THELYPTERIS DRYOPTERIS (L.) Slosson (*Phegopteris Dryopteris* (L.) Fée). — Oak fern. Maple woods; frequent. For discussion of generic name *Thelypteris* see *Rhodora*, 21 : 173. 1919.
- THELYPTERIS HEXAGONOPTERA (Michx.) Weatherby (*Phegopteris hexagonoptera* (Michx.) Fée). — Beech fern. Along streams in hemlock forest.
- THELYPTERIS PHEGopteris (L.) Slosson (*Phegopteris polypodioides* Fée). — Long beech fern. Moist banks in hemlock forest.
- THELYPTERIS PALUSTRIS (Salisb.) Schott var. PUBESCENS (Lawson) Fernald (*Aspidium Thelypteris* (L.) Sw. See Fernald, *Rhodora*, 31 : 34. 1929). — Marsh shield fern. Flood plain of Carp River; common.
- THELYPTERIS FRAGRANS (L.) Schott (*Aspidium fragrans* (L.) Sw.). — Fragrant shield fern. Under rock ledges.
- THELYPTERIS GOLDIANA (Hook.) Nieuwl. (*Aspidium Goldianum* Hook.). — Goldie's fern. Seen at one point along Carp River.
- THELYPTERIS FILIX-MAS (L.) Nieuwl. (*Aspidium Filix-mas* (L.) Sw.). — Male fern. Rocky woods; occasional.
- THELYPTERIS CRISTATA (L.) Nieuwl. — Swamp shield fern. Low ground.
- THELYPTERIS SPINULOSA (O. F. Müll.) Nieuwl. — Along wood road from Union Bay.
- THELYPTERIS SPINULOSA var. INTERMEDIA (Muhl.) Nieuwl. — Wood fern. One of the commonest ferns in the climax maple forest.
- POLYSTICHUM LONCHITIS (L.) Roth. — Holly fern. On rocky summit of north range; occasional.
- POLYSTICHUM BRAUNII (Spencer) Fée var. PURSHII Fernald (*Polystichum Braunii* of American authors. See Fernald, *Rhodora*, 30 : 28-30. 1928). — Braun's holly fern. Rocky woods; occasional.
- ATHYRIUM ACROSTICHOIDES (Sw.) Diels (*Asplenium acrostichoides* Sw.). — Silvery spleenwort. Base of rocks near Little Carp Lake; apparently not common.

- ATHYRIUM ANGUSTUM (Willd.) Presl. (*Asplenium Filix-foemina* of authors). — Lady fern. In hemlock forest; common.
- ASPENIUM TRICHOMANES L. — Maidenhair spleenwort. Crevices and ledges of rock; frequent.
- PELLAEA GLABELLA Mett. — Cliff brake. Collected by Dr. G. H. Conklin in 1932.
- ADIANTUM PEDATUM L. — Maidenhair fern. Frequent in maple woods.
- PTERIDIUM LATIUSCULUM (Desv.) Hieron. (*Pteris aquilina* of authors). — Common brake. Frequent.
- POLYPODIUM VIRGINIANUM L. (*P. vulgare* of authors. See *Rhodora*, 24 : 125. 1922). — Common polypody. Common on talus slope above Carp River.

4. ISOËTACEAE (Quillwort Family)

- ISOËTES MACROSPORA Dur. — Quillwort. In shallow water, margin of Carp Lake.
- ISOËTES ECHINOSPORA Dur. var. BRAUNII (Dur.) Engelm. — Carp Lake, with the preceding species; frequent.

5. EUISETACEAE (Horsetail Family)

- EUISETUM ARVENSE L. — Common horsetail. Gravelly open soils.
- EUISETUM PRATENSE Ehrh. — Meadow horsetail. Rock crevices and shores.
- EUISETUM SYLVATICUM L. — Wood horsetail. Frequent in moist, shaded situations. Checked by Dr. J. H. Schaffner. This is the smooth much-branched form, which Dr. M. L. Fernald has called *E. sylvaticum* L. var. *pauciramosum* Milde f. *multiramosum*. See *Rhodora*, 20 : 131. 1918.
- EUISETUM LIMOSUM L. (*E. fluviatile* of Gray's Manual. See *Rhodora*, 23 : 43. 1921). — Pipes. Along Carp River.
- EUISETUM HYEMALE L. — Reported by Ruthven (7) about the shores of Carp Lake. Undoubtedly one of the American varieties of this species.
- EUISETUM LAEVIGATUM A. Br. — Smooth scouring rush. Lake shores.
- EUISETUM VARIEGATUM Schleich. — Sandy soil along margins of Carp River Valley; occasional.
- EUISETUM SCIRPOIDES Michx. — Dwarf horsetail. Dry banks in woods; occasional.

6. LYCOPODIACEAE (Club-Moss Family)

LYCOPODIUM SELAGO L. — Reported as "common in the aspen zone" (Ruthven, 7).

LYCOPODIUM LUCIDULUM Michx. — Frequent in the hemlock forest.

LYCOPODIUM ANNOTINUM L. — Common in the hemlock forest.

LYCOPODIUM CLAVATUM L. — Club moss. Hemlock woods; occasional.

LYCOPODIUM OBSCURUM L. var DENDROIDEUM (Michx.) D. C. Eaton. — Ground pine. Woods; frequent.

LYCOPODIUM COMPLANATUM L. — Trailing Christmas green. Wooded ridges in rather dry soil; occasional.

LYCOPODIUM TRISTACHYUM Pursh. — Dry soil, summit of range; occasional.

7. SELAGINELLACEAE (Selaginella Family)

SELAGINELLA RUPESTRIS (L.) Spring. — Dwarf club moss. Forms thick mats on rocky summit of range; common.

SPERMATOPHYTA (SEED PLANTS)

8. TAXACEAE (Yew Family)

TAXUS CANADENSIS Marsh. — Ground hemlock. Yew. Woodland streams.

9. PINACEAE (Pine Family)

PINUS STROBUS L. — White pine. Straggling specimens of this pine occur along the Lake Superior shore, as well as along the main range near the top. It is not common in the climax forests of hemlock and maple. Occasionally, however, a few very large trees may be found towering above the rest of the forest. The presence of these few trees in the climax is probably to be explained by the existence of very large windfalls at one time, which permitted the young trees to have light for a sufficient time to compete successfully with the climax trees of the immediate neighborhood. There is no evidence to show that these trees formed a recent developmental stage of the sere.

PINUS RESINOSA Ait. — Red pine. Often called "Norway pine" in Michigan. Found in xeric situations on the higher southern

slopes, and occasionally along the Lake Superior shore. It is fairly common along the top and the south side of the north range, usually much dwarfed at the summit. Not found as a constituent of the climax forest. (See Pl. V, Fig. 2; Pl. VI, Fig. 2.)

PINUS BANKSIANA Lamb. — Gray pine. "Jack pine." Sterile soil; apparently infrequent in the Porcupines.

LARIX LARICINA (Du Roi) Koch. — Tamarack. Boggy ground in the river valleys.

PICEA CANADENSIS (Mill.) BSP. — White spruce. Occasional along the margin of Carp River Valley. Small trees along the shore of Lake Superior; rarely in openings in the hemlock forest.

PICEA MARIANA (Mill.) BSP. — Black spruce. Boggy ground; occasional.

TSUGA CANADENSIS (L.) Carr. — Hemlock. This is the commonest tree of the lower elevations and the dominant species on the northwest slope of the first range (Pl. V, Fig. 1). In places it occurs in almost pure stands, forming dense forests which only a few other tree species are able to invade. In 1923 a fire destroyed several square miles of hemlock forest on the north side of the range.

ABIES BALSAMEA (L.) Mill. — Balsam fir. Seedlings and immature trees occur in the sunnier parts of windfall areas in the lower climax forest; also along the shore of Lake Superior.

THUJA OCCIDENTALIS L. — Arbor vitae. White cedar. Common and often large along the shore line of Lake Superior. Dwarfed specimens are not uncommon in rock crevices.

JUNIPERUS COMMUNIS L. var. *MONTANA* Ait. — Common on ledges and exposed rock. On the rocky summit of the range, where weather conditions are severe, it forms dense, closely appressed mats.

JUNIPERUS COMMUNIS L. var. *DEPRESSA* Pursh. — Low juniper. Occasional on summit of range.

10. TYPHACEAE (Cattail Family)

TYPHA LATIFOLIA L. — Broad-leaved cattail. Low ground.

11. SPARGANIACEAE (Bur-Reed Family)

SPARGANIUM EURYCARPUM Engelm. — Large bur reed. Common along Carp River.

SPARGANIUM AMERICANUM Nutt. — In Carp Lake.

SPARGANIUM FLUCTUANS (Morong) Robinson. — Floating bur reed.
Leaves sometimes 1.0–1.5 m. long. Little Carp Lake.

12. NAJADACEAE (Pondweed Family)

POTAMOGETON NATANS L. — This and the following species more or less common in Carp Lake.

POTAMOGETON AMPLIFOLIUS Tuckerm.

POTAMOGETON GRAMINEUS L. var. GRAMINIFOLIUS Fries (*P. heterophyllus* of authors. See *Rhodora*, 23:189. 1921).

POTAMOGETON PRAELONGUS Wulf.

POTAMOGETON RICHARDSONII (Benn.) Rydb. — The specimens collected had the well-developed stipules of *P. Richardsonii*, but the obtuse leaves of *P. perfoliatus*.

POTAMOGETON EPIHYDRUS Raf. var. NUTTALLII (C. & S.) Fern.

POTAMOGETON ZOSTERIFORMIS Fernald (*P. zosterifolius* of Gray's *Manual*. See Fernald, *Mem. Am. Acad. Arts and Sci.*, 17, Pt. I, p. 37. 1932).

POTAMOGETON OBTUSIFOLIUS Mert. & Koch. — Infrequent.

POTAMOGETON PUSILLUS L. — The specimens examined included var. *typicus* and var. *mucronatus* (Fieber) Graebner.

NAJAS FLEXILIS (Willd.) Rostk. & Schmidt. — Common in Carp River.

13. ALISMATACEAE (Water-Plantain Family)

SAGITTARIA LATIFOLIA Willd. f. GRACILIS (Pursh) Robinson. — Apparently the commonest form.

SAGITTARIA HETEROPHYLLA Pursh. — The form known as var. *rigida* found at Little Carp Lake.

14. Hydrocharitaceae (Frog's-Bit Family)

VALLISNERIA AMERICANA Michx. (see *Rhodora*, 20:109. 1918). — Tape grass. "Forms extensive mats in Carp Lake" (Ruthven, 7).

15. CYPERACEAE (Sedge Family)

DULICHIMUM ARUNDINACEUM (L.) Britton. — Common in wet open ground.

ELEOCHARIS OBTUSA (Willd.) Schultes. — Low ground; common.

- ELEOCHARIS PALUSTRIS (L.) R. & S. — Common spike rush. Carp River. The mature akenes of the material found are more nearly the shape of those of *E. Smallii* Britton, but some other characters do not check for this species. See Fernald and Brackett, *Rhodora*, 31 : 57-77. 1929.
- ELEOCHARIS ACICULARIS (L.) R. & S. (see Svenson, *Rhodora*, 31 : 183-187. 1929). — In Carp River, often with long submersed leaves.
- SCIRPUS ACUTUS Muhl. (*Scirpus occidentalis* (Wats.) Chase. See *Rhodora*, 22 : 55. 1920). — Bulrush. Common.
- SCIRPUS ATROVIRENS Muhl. var. GEORGIANUS (Harper) Fernald.
- SCIRPUS CYPERINUS (L.) Kunth var. PELIUS Fernald. — Wool grass. Flood plains; common. Reported simply as *C. cyperinus* in Part I.
- MARISCUS MARISCOIDES (Muhl.) Kuntze (*Cladium mariscoides* (Muhl.) Torr. See *Rhodora*, 25 : 49. 1923). — Twig rush. Low ground; occasional.
- CAREX TRIBULOIDES Wahl. — Low ground.
- CAREX PROJECTA Mackenzie (*C. tribuloides* Wahl. var. *reducta* Bailey. See *Bull. Torr. Bot. Club*, 35 : 264. 1908). — Necklace sedge. Woodland swales.
- CAREX CRAWFORDII Fernald. — Moist ground; frequent.
- CAREX MIRABILIS Dewey. — Along wood road from Union Bay.
- CAREX ADUSTA Boott. — Dry soil on main range; frequent.
- CAREX ANGUSTIOR Mackenzie (*C. stellulata* var. *angustata* Carey). — The writer is indebted to Dr. M. L. Fernald, of Harvard University, for identification of this species.
- CAREX INTERIOR Bailey (*C. scirpoides* of *Gray's Manual*). — In cedar swamps.
- CAREX CANESCENS L. var. DISJUNCTA Fernald. — Low ground.
- CAREX BRUNNESCENS (Pers.) Poir. — Cedar swamps.
- CAREX DEWEYANA Schwein. — Dry open ground.
- CAREX TRISPERMA Dewey. — Cedar swamps.
- CAREX TENELLA Schk. — Same locality as for the preceding species.
- CAREX ROSEA Schk. — In wooded areas.
- CAREX VULPINOIDEA Michx. — Low ground; common.
- CAREX STIPATA Muhl. — Low ground.
- CAREX CRINITA Lam. var. GYNANDRA (Schwein.) Schwein. & Torr. — Low ground. Reported simply as *C. crinita* in Part I.
- CAREX LENTICULARIS Michx. — Low ground.

- CAREX STRICTA Lam. — Flood plain, Carp River.
 CAREX LEPTALEA Wahl. — Cedar swamps.
 CAREX UMBELLATA Schk. — Dry ground along main range.
 CAREX COMMUNIS Bailey. — Same situation as for the preceding species.
 CAREX LAXIFLORA Lam. — Wood road from Union Bay.
 CAREX LAXIFLORA Lam. var. PATULIFOLIA (Dewey) Carey.
 CAREX LAXIFLORA Lam. var. BLANDA (Dewey) Boott.
 CAREX OEDERI Retz. var. PUMILA (Cosson & Germain) Fernald.
 — Wet shores; frequent. Reported simply as *C. Oederi* in Part I.
 CAREX ARCTATA Boott. — Maple woods; occasional.
 CAREX DEBILIS Michx. var. RUDGEI Bailey. — Wooded areas.
 CAREX SCABRATA Schwein. — Low ground.
 CAREX LASIOCARPA Ehrh. (*C. filiformis* of *Gray's Manual*). — Common.
 CAREX HOUGHTONII Torr. — Dry soil on main range; occasional.
 CAREX RIPARIA Curtis var. LACUSTRIS (Willd.) Küken. — Low ground.
 CAREX PSEUDO-CYPERUS L. — Low wet ground.
 CAREX RETRORSA Schwein. — Low ground; common.
 CAREX INTUMESCENS Rudge. — Low ground in woods; occasional.
 CAREX ROSTRATA Stokes var. UTRICULATA (Boott) Bailey. — Low ground.
 CAREX TUCKERMANI Dewey. — Low ground; occasional.

16. GRAMINEAE (Grass Family)

- BROMUS KALMII A. Gray. — Summit of range; occasional.
 BROMUS CILIATUS L. — Wood chess. Margins of wooded areas; frequent.
 SCHIZACHNE PURPURASCENS (Torr.) Swallen (*Melica striata* of authors. *Avena Torreyi* Nash. See Hitchcock, *Manual of the Grasses of the United States*, p. 205. 1935). — False melic.
 MELICA SMITHII (Porter) Vasey (*Avena Smithii* Porter). — Smith's melic. In maple woods; occasional.
 FESTUCA ELATIOR L. — Tall fescue grass. Introduced in places.
 FESTUCA OVINA L. — Sheep fescue. Dry open ground; occasional.
 FESTUCA OCCIDENTALIS Hook. — Western fescue grass. Rocky ground; occasional.
 GLYCERIA CANADENSIS (Michx.) Trin. — Rattlesnake grass. Flood plain of Carp River; common.

- GLYCERIA STRIATA (Lam.) Hitchc. (*G. nervata* of Gray's *Manual*).
— Fowl manna grass. Low, wet ground; common.
- GLYCERIA NEOGAEA Steud. (*G. Fernaldii* (Hitchc.) St. John. *G. pal-
lida* var.). — Margin of Carp Lake.
- GLYCERIA BOREALIS (Nash) Batchelder. — Low ground.
- POA PALUSTRIS L. (*Poa triflora* of authors. See *Rhodora*, 18:235.
1916). — Fowl meadow grass. Wet ground.
- POA PRATENSIS L. — Kentucky bluegrass. Summit of range and
around clearings; frequent.
- POA ANNUA L. — Dwarf meadow grass. An occasional introduction.
- POA COMPRESSA L. — Canada bluegrass. Summit of range and
around clearings; frequent.
- PHRAGMITES COMMUNIS Trin. — Reed grass. Little Carp Lake.
- DACTYLIS GLOMERATA L. — Orchard grass. Introduced in places.
- AGROPYRON REPENS (L.) Beauv. — Quack grass. Introduced in
places.
- AGROPYRON CANINUM (L.) R. & S. (*A. subsecundum* (Link) Hitchc.
See Hitchcock, *Manual of the Grasses of the United States*, p. 237.
1935). — Bearded wheat grass. Dry soil on summit of range.
The form with short awns also occurs, evidently var. *tenerum*
(Vasey) Peace & Moore (see *Rhodora*, 12:61. 1910).
- ELYMUS VIRGINICUS L. — Wild rye. Low ground; occasional.
- ELYMUS RIPARIUS Wiegand (see *Rhodora*, 20:81. 1918). — Woods;
infrequent.
- ELYMUS CANADENSIS L. — Low ground; infrequent.
- ASPERELLA HYSTRIX (L.) Humb. (*Hystrix patula* of authors; *H.
Hystrix* (L.) Millsp.). — Bottle-brush grass. Maple woods; occa-
sional.
- HORDEUM JUBATUM L. — Squirreld tail grass. At Union Bay.
- DESCHAMPSIA CAESPITOSA (L.) Beauv. var. GLAUCA (Hartm.) Lindm.
(see Fernald, *Rhodora*, 28:154. 1926). — Rock crevices along
Lake Superior shore; common.
- DANTHONIA SPICATA (L.) Beauv. — Poverty oat grass. Dry soil,
summit of range; common.
- CALAMAGROSTIS CANADENSIS (Michx.) Beauv. — Bluejoint grass.
Flood plains; common.
- AGROSTIS STOLONIFERA L. — Red top. An occasional introduction.
- AGROSTIS PERENNANS (Walt.) Tuckerm. — Thin grass. Autumn
bent. In dry ground, especially "burns." Occasional.

- AGROSTIS HYEMALIS (Walt.) BSP. — Hair grass. Occasional.
- CINNA LATIFOLIA (Trev.) Griseb. — Slender wood grass. Low ground; frequent.
- SPOROBOLUS CRYPTANDRUS (Torr.) A. Gray. — Sand dropseed. Dry ground near summit of range; occasional.
- PHLEUM PRATENSE L. — Timothy. Introduced in places.
- MUHLENBERGIA FOLIOSA Trin. — Satin grass. Frequent in moist soil.
- MUHLENBERGIA UNIFLORA (Muhl.) Fernald (*Sporobolus uniflorus* (Muhl.) Scrib. & Merr. See Hitchcock, *Manual of the Grasses of the United States*, p. 367. 1935). — Low ground; infrequent.
- DILEPYRUM ERECTUM (Schreb.) Farwell (*Brachyelytrum erectum* of authors). — Bearded short husk. Maple woods; frequent.
- MILIUM EFFUSUM L. — Tall millet grass. Frequent in maple woods.
- ORYZOPSIS PUNGENS (Torr.) Hitchc. — Dry ground, summit of range.
- ORYZOPSIS ASPERIFOLIA Michx. — Gravelly soil, south slope of range; frequent.
- PHALARIS ARUNDINACEA L. — Reed canary grass. Border of Carp Lake.
- LEERSIA ORYZOIDES (L.) Sw. — Rice cut-grass. Moist ground; infrequent.
- PANICUM CAPILLARE L. — Old witch grass. Wood road from Union Bay.
- PANICUM DEPAUPERATUM Muhl. var. *PSILOPHYLLUM* Fernald. — Summit of range; frequent.
- PANICUM SUBVILLOSUM Ashe. — Same situations as for the preceding species. The writer is indebted to Dr. M. L. Fernald for the identification of this and the preceding species.
- PANICUM LINEARIFOLIUM Scribn. — Dry ground, summit of range.
- PANICUM PRAECOCIUS Hitchc. & Chase. — With the preceding species.
- PANICUM XANTHOPHYSUM A. Gray. — Dry ground; occasional.
- SETARIA LUTESCENS (Weigel) Hub. — Yellow bristle grass. Occasional as an introduction.
- SETARIA VIRIDIS (L.) Beauv. — Green bristle grass. Old camp sites.

17. ARACEAE (Arum Family)

- ARISAEMA TRIPHYLLUM (L.) Schott. — Indian turnip. Low ground in woodlands; occasional.
- CALLA PALUSTRIS L. — Water arum. Observed along Carp River.

SYMPLOCARPUS FOETIDUS (L.) Nutt. — Skunk cabbage. Reported as "occasional in alder thickets along Carp River" (Ruthven, 7).
ACORUS CALAMUS L. — Sweet flag. Low ground.

18. LEMNACEAE (Duckweed Family)

LEMNA TRISULCA L. — In small tributary of Carp River; one place.
LEMNA MINOR L. — In Carp River.

19. ERIOCAULACEAE (Pipewort Family)

ERIOCAULON SEPTANGULARE With. (*E. articulatum* of Gray's *Manual*).
— Pipewort. Lake shores.

20. JUNCACEAE (Rush Family)

JUNCUS EFFUSUS L. var. PYLAEI (Leharpe) Fernald & Wiegand.
— The writer is indebted to Dr. K. M. Wiegand of Cornell University for the identification of this variety. Low ground.
JUNCUS BUFONIUS L. — Moist open ground; occasional.
JUNCUS TENUIS Willd. — Wire grass. Along old trails.
JUNCUS DUDLEYI Wiegand. — Rock crevices along Lake Superior shore.
JUNCUS BREVICAUDATUS (Engelm.) Fernald. — Lake shores.
JUNCUS CANADENSIS J. Gay. — "In shallow water about the shore of Carp Lake" (Ruthven, 7) list.
JUNCUS PELOCARPUS Mey. — Vicinity of Little Carp Lake.
JUNCUS NODOSUS L. — Shore of Lake Superior.

21. LILIACEAE

UVULARIA GRANDIFLORA Sm. — Large bellwort. Gravelly soil on main ridge; frequent.
OAKESIA SESSILIFOLIA (L.) Wats. — Maple woods; occasional.
ALLIUM TRICOCCUM Ait. — Wild leek. Woods; occasional.
LILIUM CANADENSE L. — Wild yellow lily. Low ground; occasional.
CLINTONIA BOREALIS (Ait.) Raf. — Low woods; frequent.
SMILACINA RACEMOSA (L.) Desf. — False Solomon's seal. Rocky woods.
MAIANTHEMUM CANADENSE Desf. — False lily-of-the-valley. Woods; frequent.
STREPTOPUS AMPLEXIFOLIUS (L.) DC. — Woods; not common.
STREPTOPUS ROSEUS Michx. — Twisted stalk. Woods; frequent.

POLYGONATUM PUBESCENS (Willd.) Pursh (*P. biflorum* of Gray's *Manual*). — Solomon's seal. Carp River Valley.

TRILLIUM GRANDIFLORUM (Michx.) Salisb. — White trillium. Maple woods; common.

TRILLIUM DECLINATUM (A. Gray) Gleason. — Woods; occasional.

SMILAX HERBACEA L. — Carrion flower. Low open ground.

SMILAX ECIRRHATA (Engelm.) Wats. — Woodland borders; occasional.

22. IRIDACEAE (Iris Family)

IRIS VERSICOLOR L. — Larger blue flag. Low ground.

23. ORCHIDACEAE (Orchid Family)

CYPRIPEDIUM ACAULE Ait. — Pink moccasin flower. Low woods; occasional.

HABENARIA BRACTEATA (Willd.) R. Br. — Low ground; not common.

HABENARIA HYPERBOREA (L.) R. Br. — In mucky bogs or "cedar swamps"; occasional. (See Pl. VI, Fig. 1.)

HABENARIA DILATATA (Pursh) Gray. — Same habitat as for the preceding species; rare.

HABENARIA OBTUSATA (Pursh) Richards. — In bogs; occasional.

HABENARIA ORBICULATA (Pursh) Goldie (see *Rhodora*, 35: 398. 1933). — In tamarack swamp; infrequent.

HABENARIA LACERA (Michx.) R. Br. — Flood plain of Carp River; rare.

HABENARIA PSYCHODES (L.) Sw. — Purple fringed orchis. In swamps; frequent.

SPIRANTHES CERNUA (L.) Richard var. OCHROLEUCA (Rydb.) Ames. — Collected on bluffs by Dr. Fassett.

EPIPACTIS REPENS (L.) Crantz var. OPHIOIDES (Fernald) A. A. Eaton. — Rattlesnake plantain. Occasional in the hemlock forest.

EPIPACTIS TESSELATA (Lodd.) A. A. Eaton. — Rattlesnake plantain. Woods; occasional.

EPIPACTIS DECIPIENS (Hook.) Ames. — Vicinity of Little Carp Lake.

LISTERA CONVALLARIOIDES (Sw.) Torr. — Woods; not common.

CORALLORRHIZA TRIFIDA Chat. — Woods; not common.

CORALLORRHIZA MACULATA Raf. — Coralroot. Woods; frequent.

MALAXIS UNIFOLIA Michx. (see Britton and Brown, *Illustrated Flora*, Edition 2, 1: 571). — Low ground, shore of Carp Lake.

24. SALICACEAE (Willow Family)

- POPULUS TACAMAHACCA Mill. (*P. balsamifera* of authors. See *Journ. Arnold Arb.*, 1: 61. 1919.) — Balsam poplar. A few small specimens noted along the Lake Superior shore.
- POPULUS TREMULOIDES Michx. — American aspen. Common along the main range and Lake Superior shore.
- POPULUS GRANDIDENTATA Michx. — Large-toothed aspen. Common on the talus slope below the first range.
- SALIX NIGRA Marsh. — Black willow. Lake shores.
- SALIX LUCIDA Muhl. — Shining willow. Low open ground; common.
- SALIX PEDICELLARIS Pursh. — Bog willow. Low ground.
- SALIX DISCOLOR Muhl. — Low ground.
- SALIX PETIOLARIS J. E. Smith. — Frequent.
- SALIX HUMILIS Marsh. — Prairie willow. In dry soil top of range and in rock crevices, Lake Superior shore.
- SALIX BEBBIANA Sarg. (*S. rostrata* of *Gray's Manual*). — Woodland borders and lake shores.

25. MYRICACEAE (Sweet-Gale Family)

- MYRICA GALE L. — Sweet gale. Low ground.
- MYRICA GALE L. var. SUBGLABRA (Chev.) Fernald (see *Rhodora*, 16: 167. 1914). — Both the species and the variety found in the vicinity of Little Carp Lake, the former apparently less common than the latter.

26. BETULACEAE (Birch Family)

- CORYLUS CORNUTA Marsh. (*Corylus rostrata* of *Gray's Manual*). — Beaked hazelnut. On talus slope, in windfalls, and along Lake Superior shore; frequent.
- OSTRYA VIRGINIANA (Mill.) K. Koch. — Hop hornbeam. Ironwood. In the hardwood forest; frequent.
- BETULA PAPYRIFERA Marsh. — Paper birch. "White birch" of the Great Lakes region. A border tree of the hardwood forests and lakes. Also along the Lake Superior shore; common.
- BETULA LUTEA Michx. f. — Yellow birch. This species is common in both the hemlock and the hardwood forests. I believe (with Wiegand) that *B. allegheniensis* is to be classed as an ecological variant of *B. lutea*.

ALNUS CRISPA (Ait.) Pursh. — Green alder. Near summit of the range; occasional.

ALNUS INCANA (L.) Moench. — Speckled alder. Low ground; common in places.

27. FAGACEAE (Beech Family)

QUERCUS BOREALIS Michx. f. (*Q. rubra* L. var. *ambigua* (Michx. f.) Fernald. See Sargent in *Rhodora*, 18:48. 1916). — Northern red oak. Summit of gravelly ridges; frequent. All trees seen were small.

QUERCUS COCCINEA Muenchh. — Scarlet oak. Seen at one place along main ridge. The specimen noted, a tree about 25 m. tall, did not seem to be quite typical of the species, differing in the comparative length of leaf lobes, angle of sinus, and unusually small size of cups. The occurrence of this group in northern Michigan needs further investigation.

28. URTICACEAE (Nettle Family)

ULMUS AMERICANA L. — American elm. Apparently not common in the Porcupine Mountains.

HUMULUS LUPULUS L. — Hop. Low ground; occasional.

LAPORTEA CANADENSIS (L.) Gaud. — Wood nettle. Moist woods; occasional.

URTICA PROCERA Muhl. (*U. gracilis* of authors. See *Rhodora*, 28: 195. 1926). — Common wild nettle. Common in low ground.

URTICA LYALLII Wats. — The specimens, collected by E. A. Bessey in the vicinity of Little Carp Lake, do not seem quite typical for the species.

29. SANTALACEAE (Sandalwood Family)

COMANDRA UMBELLATA (L.) Nutt. — Bastard toadflax. Dry soil on ridge.

30. ARISTOLOCHIACEAE (Birthwort Family)

ASARUM CANADENSE L. — Wild ginger. Along woodland streams; occasional.

31. POLYGONACEAE (Smartweed Family)

RUMEX BRITANNICA L. — Great water dock. Flood plain of Carp River.

- RUMEX VERTICILLATUS L. — Swamp dock. Low ground.
- RUMEX OBTUSIFOLIUS L. — Broad-leaved dock. Introduced along woodland roads.
- RUMEX ACETOSELLA L. — Sheep sorrel. Introduced in places.
- POLYGONUM AVICULARE L. — Knotweed. Introduced along paths and roads.
- POLYGONUM DOUGLASHI Greene. — Common in dry soil along summit of the range.
- POLYGONUM AMPHIBIUM L. — Seen in Carp Lake; apparently not common.
- POLYGONUM MUHLENBERGII (Meisn.) Wats. — Flood plains; occasional.
- POLYGONUM PUNCTATUM Ell. (*P. acre* var. *leptostachyum* of Gray's *Manual*. See *Rhodora*, 29 : 77. 1927). — Water smartweed. Low ground, common.
- POLYGONUM HYDROPIPEROIDES Michx. — Low ground; occasional.
- POLYGONUM PERSICARIA L. — Lady's thumb. Introduced near Union Bay.
- POLYGONUM CILINODE Michx. — Fringed bindweed. Along the main ridge in places.

32. CHENOPODIACEAE (Goosefoot Family)

- CHENOPODIUM CAPITATUM (L.) Asch. (*Blitum capitatum* L.). — Strawberry blite. At Union Bay.
- CHENOPODIUM HYBRIDUM L. — Maple-leaved goosefoot. Upland wooded areas and along main ridge; occasional.
- CHENOPODIUM ALBUM L. — Lamb's quarters. Introduced along wood roads; occasional.

33. CARYOPHYLLACEAE (Pink Family)

- CERASTIUM ARVENSE L. — Forms mats on summit of range; frequent. Evidently native.
- CERASTIUM VULGATUM L. — Mouse-ear chickweed. Introduced along wood roads.
- SILENE ANTIRRHINA L. — Sleepy catchfly. Common in dry ground, summit of range.

34. CERATOPHYLLACEAE (Hornwort Family)

- CERATOPHYLLUM DEMERSUM L. — Hornwort. Carp River; frequent.

35. NYMPHAEACEAE (Water-Lily Family)

NYMPHOZANTHUS VARIEGATUS (Englem.) Fernald (*Nymphaea americana* of authors. See *Rhodora*, 21:183. 1919). — In lakes; common.

NYMPHAEA TUBEROSA Paine (see *Rhodora*, 18; 161. 1916). — Specimens obtained in Carp River were first thought to be *N. odorata*, but further studies suggested by Dr. H. S. Conard have led the writer to believe that the specimens collected are *N. tuberosa* as that species is now understood.

BRASENIA SCHREBERI Gmel. — Water shield. Carp River.

36. RANUNCULACEAE (Buttercup Family)

AQUILEGIA CANADENSIS L. — Wild columbine. Frequent as a crevice plant in rocky situations.

ACTAEA ALBA (L.) Mill. — White baneberry. Woodlands; frequent.

ACTAEA RUBRA (Ait.) Willd. — Red baneberry. Maple climax; not common. The majority of the plants seen had white fruits (f. *neglecta* (Gillman) Robinson).

COPTIS GROENLANDICA (Oeder) Fernald (*C. trifolia* of authors. See Fernald in *Rhodora*, 31:136. 1929). — Goldthread. Boggy ground in the climax forest; frequent.

CALTHA PALUSTRIS L. — Marsh marigold. Wet ground; frequent.

RANUNCULUS AQUATILIS L. var. CAPILLACEUS DC. (*Batrachium trichophyllum* (Chaix) F. Schultz). — Water buttercup. The common species in Carp River.

RANUNCULUS REPTANS L. var. OVALIS (Bigel.) T. & G. (*R. Flamula* var. *reptans* of Gray's *Manual*. See *Rhodora*, 19:135. 1917). — Muddy banks.

RANUNCULUS ABORTIVUS L. — Maple woods; frequent.

RANUNCULUS RECURVATUS Poir. — Rough crowfoot. Along forest streams; frequent.

RANUNCULUS PENNSYLVANICUS L. f. — Flood plains; occasional.

RANUNCULUS REPENS L. var. VILLOSUS Lamotte (see *Rhodora*, 21:169. 1919). — Creeping buttercup. Mouth of Little Carp River; apparently native, but not common.

RANUNCULUS ACris L. — Meadow buttercup. Introduced in places.

THALICTRUM DIOICUM L. — Early meadow rue. Woods.

THALICTRUM DASycarpum Fisch. & Lall. — Low ground; frequent.

- ANEMONE CANADENSIS L. — Anemone. Low ground; common.
- ANEMONE QUINQUEFOLIA L. — Wood anemone. Moist soil in woodlands; frequent.
- HEPATICA AMERICANA (DC.) Ker (*H. triloba* of *Gray's Manual*. See *Rhodora*, 19: 45. 1917). — Hepatica. Open woods in gravelly soil; frequent.
- HEPATICA ACUTILOBA DC. — Acute-lobed hepatica. Apparently infrequent.
- CLEMATIS VIRGINIANA L. — Virgin's bower. Low ground; frequent.

37. BERBERIDACEAE (Barberry Family)

- CAULOPHYLLUM THALICTROIDES (L.) Michx. — Blue cohosh. Woods; occasional.

38. PAPAVERACEAE (Poppy Family)

- SANGUINARIA CANADENSIS L. — Bloodroot. Maple woods; frequent.

39. FUMARIACEAE (Fumitory Family)

- ADLUMIA FUNGOSA (Ait.) Greene. — Climbing fumitory. Borders of hardwood forest; frequent.
- DICENTRA CUCULLARIA (L.) Bernh. — Dutchman's Breeches. Moist woodlands.
- DICENTRA CANADENSIS (Goldie) Walp. — Squirrel corn. Maple woods.
- CORYDALIS SEMPERVIRENS (L.) Pers. — Pink corydalis. Open stony ground; occasional.
- CORYDALIS AUREA Willd. — Golden corydalis. In burned areas along Lake Superior shore.

40. BRASSICACEAE (Mustard Family)

- LEPIDIUM DENSIFLORUM Schrad. (*L. apetalum* of *Gray's Manual*). — Peppergrass. Introduced along wood roads; occasional.
- CAPSELLA BURSA-PASTORIS (L.) Medic. — Shepherd's purse. Introduced in places.
- BRASSICA ARVENSIS (L.) Ktze. (*Sinapis arvensis* L.). — Charlock mustard. Introduced at Union Bay.
- SISYMBRIUM ALTISSIMUM L. (*Norta altissima* (L.) Britton). — Tumble mustard. Sparingly introduced.
- RORIPA PALUSTRIS (L.) Bess. var. *HISPIDA* (Desv.) Rydb. (under

Radicula, *Gray's Manual*). — Marsh cress. Along streams; occasional.

BARBAREA VULGARIS R. Br. — Yellow rocket. Introduced along wood roads.

CARDAMINE PENNSYLVANICA Muhl. — Bitter cress. Upper reaches of Carp River; occasional.

ARABIS HOLBOELLII Hornem. — Collected on summit of bluff overlooking Carp Lake.

ARABIS HIRSUTA (L.) Scop. — Rock cress. Bare rock along summit of range; frequent.

ARABIS LAEVIGATA (Muhl.) Poir. — Rock cress. Dry soil along main range.

ARABIS BRACHYCARPA (T. & G.) Britton. — Along summit of range; frequent.

41. SARRACENIACEAE (Pitcher-Plant Family)

SARRACENIA PURPUREA L. — Pitcher plant. Peaty soil along Carp River.

42. SAXIFRAGACEAE (Saxifrage Family)

MITELLA NUDA L. — Bishop's cap. Low woods; frequent.

CHRYSOSPLENIUM AMERICANUM Schwein. — Golden saxifrage. Low ground; occasional.

RIBES CYNOSBATI L. — Wild gooseberry. Maple woods; occasional.

RIBES GLANDULOSUM Grauer. — Fetid currant. Low ground; occasional.

43. HAMAMELIDACEAE (Witch-Hazel Family)

HAMAMELIS VIRGINIANA L. — Witch hazel. Apparently scarce.

44. ROSACEAE (Rose Family)

PHYSOCARPUS OPULIFOLIUS (L.) Maxim. — Ninebark. Exposed rock crevices along the main range and the shore of Lake Superior; frequent.

SPIRAEA ALBA Du Roi (*Spiraea salicifolia* of *Gray's Manual*). — Meadowsweet. Low open ground; common.

FRAGARIA VIRGINIANA Duchesne. — Common strawberry. Crevices of rocks along Lake Superior shore.

FRAGARIA VESCA L. var. AMERICANA Porter. — American wood strawberry. Bordering the maple climax along the main range.

- WALDSTEINIA FRAGARIOIDES (Michx.) Tratt. — Barren strawberry.
Dry open ground; infrequent.
- POTENTILLA PALUSTRIS (L.) Scop. (*Comarum palustre* L.). — Marsh cinquefoil. Low ground.
- POTENTILLA ARGUTA Pursh. — Dry soil, along summit of main range.
- POTENTILLA NORVEGICA L. var. *HIRSUTA* (Michx.) Lehm. (*P. monspeliensis* of *Gray's Manual*). — Rough cinquefoil. Occasional.
- POTENTILLA TRIDENTATA Ait. — Three-toothed cinquefoil. A common crevice plant along summit of range (var. *hirsutifolia* reported by Fassett).
- POTENTILLA CANADENSIS L. — Five-finger. Dry soil on main range.
- GEUM STRICTUM Ait. — Yellow avens. Moist open ground; frequent.
- RUBUS IDAEUS L. var. *STRIGOSUS* (Michx.) Maxim. (*R. idaeus* var. *aculeatissimus* of *Gray's Manual*. See *Rhodora*, 21:89. 1919). — Red raspberry. Open ground; common.
- RUBUS PARVIFLORUS Nutt. — Salmonberry. Abundant as second growth over forested areas. This species has recently been divided by Dr. M. L. Fernald into a number of geographic varieties. (See *Rhodora*, 37:348-441. 1935.)
- RUBUS PUBESCENS Raf. (*R. triflorus* of *Gray's Manual*. See *Rhodora*, 11:236. 1909). — Dwarf rubus. The form of this plant occurring along the rocky shore of Lake Superior is often very slender, with almost sessile terminal leaflets and narrower stipules than the usual form.
- RUBUS ALLEGHENIENSIS Porter. — Common highbush blackberry; abundant in dry open ground.
- RUBUS AMNICOLUS Blanchard (included by authors under *R. pergratus* Blanchard. See *Rhodora*, 8:170. 1906). — The specimens, 6-9 dm. tall, mostly collected on talus slope along main ridge.
- RUBUS CANADENSIS L. — Open, well-drained ground; frequent.
- RUBUS SETOSUS Bigel. — Dry rocky ground. The writer is indebted to Dr. L. H. Bailey for verification of this and the preceding species.
- RUBUS NIGRICANS Rydb. — Open ground; occasional.
- RUBUS HISPIDUS L. — Running swamp blackberry. Low ground.
- RUBUS FLAGELLARIS Willd. (*R. procumbens* of authors; *R. villosus* of *Gray's Manual*). — Dewberry. Along Lake Superior shore; occasional.
- AGRIMONIA GRYPOSEPALA Wallr. — Agrimony. Dry soil in aspen-birch woodlands; occasional.

AGRIMONIA STRIATA Michx. — Dry soil; occasional.

ROSA ACICULARIS Lindl. var. ROTUNDA Erlanson (see *Pap. Mich. Acad. Sci., Arts and Letters*, 5: 84. 1925. Included in *R. acicularis* var. *Bourgeauiana* of *Gray's Manual*). — On dry, exposed summit of the range or on talus slopes, with prostrate stems from the crevices of rocks. Var. *Bourgeauiana* apparently occurs also.

ROSA BLANDA Ait. var. GLANDULOSA Schuette. (*R. blanda* $\times$ *acicularis*, according to Rydberg in *North Am. Fl.*, Vol. 22. 1918). — These specimens were examined by Miss Erlanson, who says that they have indications of a hybrid origin in the abortive hips. The environmental conditions under which the plants grow are severe. The stems are often long and crooked, adapting themselves to the rock crevices. The forms of this species found on the summit of the range are often only 3–4 dm. high, approaching var. *hispida* Farwell.

ROSA PALUSTRIS Marsh. (*R. carolina* of *Gray's Manual*. See *Rhodora*, 20: 91. 1918). — Swamp rose. Flood plains; frequent.

PRUNUS SUSQUEHANAE Willd. (*P. pumila* of Ruthven's list. See *Rhodora*, 25: 73. 1923). — "On the upper beach of Lake Superior."

PRUNUS PENNSYLVANICA L. f. — Pin cherry. Dry ground, especially over "burns."

PRUNUS VIRGINIANA L. — Chokecherry. Margins of woodlands; frequent.

PRUNUS SEROTINA Ehrh. — Wild black cherry. Dry upland soil; frequent. Small trees occur on talus slopes.

SORBUS AMERICANA Marsh. — Mountain ash. Low ground; occasional.

SORBUS DUMOSA Greene (*Pyrus sitchensis* of *Gray's Manual*. See *Rhodora*, 23: 266. 1921). — On talus slope of main range. E. A. Bessey.

MALUS PUMILA Mill. — Common apple. Introduced around old mining properties.

ARONIA MELANOCARPA (Michx.) Britton (*Pyrus melanocarpa* of *Gray's Manual*). — Black chokeberry. Low open ground. This is the common form in Michigan.

AMELANCHIER SANGUINEA (Pursh) DC. (*A. spicata* of *Gray's Manual*). — Juneberry. Dry ground, along main ridge and talus slope. E. A. Bessey.

AMELANCHIER HUMILIS Wiegand. — Low juneberry. Rocky summit

of ridge and talus slope. Plants 6-9 or sometimes 12-15 dm. tall. The writer is indebted to Dr. K. M. Wiegand for checking this species.

AMELANCHIER LAEVIS Wiegand. — Moist ground inland; also along Lake Superior shore. This species was included under *Amelanchier canadensis* in Part I of this report.

AMELANCHIER FLORIDA Lindley. — On summit of cliff. Reported by Dr. Fassett.

CRATAEGUS BOYNTONI Beadle. — On rocky ground along main range. Specimens collected by E. A. Bessey in like situations are very similar to the preceding species, but appear to be closer to *C. straminea* Beadle. The leaves differ in being more truncate at the base, petioles less winged, and calyx lobes slightly glandular. No opportunity was afforded to examine the flowers.

CRATAEGUS DOUGLASII Lindley. — Mouth of Carp River. Seen only at this one place.

45. FABACEAE (Pea Family)

TRIFOLIUM PRATENSE L. — Red clover. Introduced; occasional.

TRIFOLIUM REPENS L. — White clover. Along wood roads. Introduced.

TRIFOLIUM HYBRIDUM L. — Alsike clover. Introduced at Union Bay.

TRIFOLIUM AGRARIUM L. — Hop clover. Along wood road.

VICIA AMERICANA Muhl. — Vetch. Shore of Lake Superior.

LATHYRUS MARITIMUS (L.) Bigel. — Lake Superior shore; frequent.

LATHYRUS OCHROLEUCUS Hook. — Wood roads; occasional.

46. GERANIACEAE (Geranium Family)

GERANIUM BICKNELLII Britton. — Dry ground along main ridge; occasional.

47. OXALIDACEAE (Wood-Sorrel Family)

OXALIS MONTANA Raf. (*O. Acetosella* of Gray's Manual. See *Rhodora*, 22: 143. 1920). — Pink wood sorrel. Woodlands, in moist soil; frequent.

48. CALLITRICHACEAE (Water-Starwort Family)

CALLITRICHE PALUSTRIS L. — Water starwort. Muddy flats along Carp River.

49. ANACARDIACEAE (Sumac Family)

- RHUS TYPHINA L. — Staghorn sumac. Dry open ground; frequent.
RHUS GLABRA L. — Smooth sumac. Occurs with the preceding species; occasional. This has the appearance of being an ecological variant of the former, rather than a well-marked species. Both forms occur as stunted plants growing from rock crevices.
RHUS TOXICODENDRON L. — Poison ivy. Woodland borders; occasional.

50. AQUIFOLIACEAE (Holly Family)

- ILEX VERTICILLATA (L.) Gray. — Winterberry. Low open ground; frequent.
NEMOPANTHUS MUCRONATA (L.) Trelease. — Mountain holly. Low open ground; occasional.

51. CELASTRACEAE (Bittersweet Family)

- CELASTRUS SCANDENS L. — Shrubby bittersweet. Along talus slope below main range; occasional.

52. ACERACEAE (Maple Family)

- ACER RUBRUM L. — Red maple. Moist open ground or border of woodlands; occasional.
ACER SACCHARUM Marsh. — Sugar maple. Dominant species of the climax maple forest. (See Part I.)
ACER SPICATUM Lam. — Mountain maple. Moist ground along shores and in forest openings; common.

53. BALSAMINACEAE (Touch-me-not Family)

- IMPATIENS BIFLORA Walt. — Spotted touch-me-not. Low ground along water courses.

54. RHAMNACEAE (Buckthorn Family)

- RHAMNUS ALNIFOLIA L'Hér. — Swamp buckthorn. Carp River Valley; occasional.
CEANOTHUS OVATUS Desf. — Smaller redroot. Dry rocky ground, especially in rock crevices. Summit of main range and along Lake Superior shore; frequent. This species was incorrectly called *C. americanus* in Part I.

55. VITACEAE (Grape Family)

PARTHENOCISSUS VITACEA (Knerr) Hitchc. — Woodbine. On talus slope of main range; occasional.

VITIS VULPINA L. — Frost grape. On talus slopes; occasional.

56. TILIACEAE (Linden Family)

TILIA AMERICANA L. — Basswood. Frequent in the climax forest. Apparently the name "basswood" is more commonly applied to this tree in the Middle West; "linden" is commoner eastward.

57. HYPERICACEAE (St. John's-Wort Family)

HYPERICUM ELLIPTICUM Hook. — Low open ground; common.

HYPERICUM BOREALE (Britton) Bicknell. — Low ground; occasional.

HYPERICUM MUTILUM L. — Low ground; frequent.

HYPERICUM VIRGINICUM L. — Low open ground; occasional.

58. CISTACEAE (Rockrose Family)

HELIANTHEMUM BICKNELLII Fernald (*H. majus* of authors. See *Rhodora*, 21:36. 1919). — On bluff; common.

LECHEA STRICTA Leggett. — Dry ground along summit of range. E. A. Bessey.

59. VIOLACEAE (Violet Family)

VIOLA CUCULLATA Ait. — Marsh blue violet. Maple woods.

VIOLA PALLENS (Banks) Brainerd. — Northern white violet. Low ground.

VIOLA BLANDA Willd. — Sweet white violet. Moist ground in woodlands; frequent.

VIOLA PUBESCENS Ait. — Downy yellow violet. Rather dry ground. Edge of woodlands near summit of range; frequent.

VIOLA ERIOCARPA Schwein. (*V. scabriuscula* of *Gray's Manual*. See *Bull. Torr. Bot. Club*, 38:194. 1911). — Smooth yellow violet.

VIOLA CANADENSIS L. — Shore of Lake Superior. Probably common in maple woods.

VIOLA CONSPERSA Reichenb. — Dog violet. Low woods.

VIOLA LABRADORICA Schrank. — Collected on bluffs by Dr. Fassett.

VIOLA ADUNCA J. E. Smith (included in *V. arenaria* of *Gray's Manual*. See *Rhodora*, 15:106-111. 1913). — Dry soil and rock crevices, summit of main range; frequent.

60. THYMELAEACEAE (Leatherwood Family)

DIRCA PALUSTRIS L. — Leatherwood. Maple woods; common.

61. ELAEAGNACEAE (Oleaster Family)

SHEPERDIA CANADENSIS (L.) Nutt. — Dry ground along summit of main range.

62. ONAGRACEAE (Evening-Primrose Family)

LUDWIGIA PALUSTRIS (L.) Ell. — Water purslane. Mouth of Carp River.

EPILOBIUM ANGUSTIFOLIUM L. — Fireweed. Common on burned areas.

EPILOBIUM DENSUM Raf. — Vicinity of Little Carp Lake. E. A. Bessey.

EPILOBIUM GLANDULOSUM Lehm. var. ADENOCAULON (Haussk.) Fernald (*E. adenocaulon* of authors. See *Rhodora*, 20:34. 1918). — Low ground; common. Some of the plants seen appeared to be nearer var. *occidentale* (Trelease) Fernald.

EPILOBIUM COLORATUM Muhl. — Low ground; occasional.

OENOTHERA BIENNIS L. var. — Evening primrose. Along summit of main ridge, often as a crevice plant. The rosette leaves of this form are linear-oblongate, finely strigose on both surfaces. The densely crowded capsules average 20 mm. in length, tapering strongly from base to apex; seeds 1.3–1.5 mm. long and 0.6–0.8 mm. wide. Evidently this is not typical *O. biennis* L. (See Bartlett in *Rhodora*, 15:52. 1913.)

OENOTHERA BIENNIS L. var. PYCNOCARPA (Atkins & Bart.) Wiegand (see *Rhodora*, 15:83. 1913). — In birch-aspen woods along main range.

CIRCAEA LATIFOLIA Hill (*E. lutetiana* of Gray's Manual. See *Rhodora*, 17:222. 1915). — Enchanter's nightshade. In maple climax; occasional.

CIRCAEA ALPINA L. — Along small streams in the climax forest.

63. HALORAGIDACEAE (Water-Milfoil Family)

MYRIOPHYLLUM FARWELLII Morong. — The commonest species in Carp River.

HIPPURIS VULGARIS L. — Mare's-tail. In Carp River.

64. ARALIACEAE (Ginseng Family)

- ARALIA RACEMOSA L. — American spikenard. Woodlands; occasional.
 ARALIA HISPIDA Vent. — Bristly sarsaparilla. Dry ground, especially over burned areas; common.
 ARALIA NUDICAULIS L. — Wild sarsaparilla. Common in the hemlock climax.

65. UMBELLIFERAE (Carrot Family)

- SANICULA GREGARIA Bicknell. — Black snakeroot. Moist ground in maple woods; apparently not common.
 HYDROCOTYLE AMERICANA L. — Water pennywort. Along water courses; frequent.
 OSMORHIZA CLAYTONI (Michx.) Clarke. — Sweet cicely. In the maple climax; frequent.
 OSMORHIZA DIVARICATA Nutt. — Woods; occasional.
 CICUTA BULBIFERA L. — Slender water hemlock. Common in low ground.
 SIUM SUAVE Walt. (*S. cicutaeifolium* of Gray's Manual. See *Rhodora*, 17: 131. 1915). — Low ground; frequent.
 CRYPTOTAENIA CANADENSIS (L.) DC. — Hqnewort. Near Union Bay; apparently not common.
 HERACLEUM LANATUM Michx. — Cow parsnip. Introduced at Union Bay.

66. CORNACEAE (Dogwood Family)

- CORNUS CANADENSIS L. — Dwarf cornel. Low ground in woodlands.
 CORNUS RUGOSA Lam. — Round-leaved dogwood. Gravelly hill-sides; frequent.
 CORNUS ASPERIFOLIA Michx. — Rough-leaved dogwood. Collected by Dr. Fassett.
 CORNUS STOLONIFERA Michx. — Red-osier dogwood. Low open ground; frequent.
 CORNUS ALTERNIFOLIA L. f. — Alternate-leaved dogwood. Maple woods; frequent.

67. ERICACEAE (Heath Family)

- MONOTROPA UNIFLORA L. — Indian pipe. Moist woodlands; occasional.

- MONOTROPA HYPOPITYS L. — Hairy pinesap. Maple climax; occasional.
- CHIMAPHILA UMBELLATA (L.) Nutt. var. CISATLANTICA Blake (see *Rhodora*, 19: 241. 1917). — Prince's pine. Hemlock climax; occasional.
- PYROLA MINOR L. — Lesser shinleaf. Vicinity of Little Carp Lake.
- PYROLA SECUNDA L. — Shinleaf. In the hemlock climax; occasional.
- PYROLA ELLIPTICA Nutt. — Shinleaf. Occasional in the hemlock forest.
- PYROLA CHLORANTHA Swartz. — Moist ground along streams in the hemlock climax; occasional. The specimens collected were of the typical form. (See *Rhodora*, 22: 51. 1920.)
- PYROLA ROTUNDIFOLIA L. var. AMERICANA (Sweet) Fernald (*P. americana* of *Gray's Manual*. See *Rhodora*, 22: 122. 1920). — Shinleaf. Woodlands; occasional.
- MONESES UNIFLORA (L.) Gray. — One-flowered shinleaf. Moist woodlands; not common.
- LEDUM GROENLANDICUM Oeder. — Labrador tea. Flood plain of Carp River, and around Little Carp Lake.
- KALMIA POLIFOLIA Wang. — Bog laurel. Boggy ground.
- CHAMAEDAPHNE CALYCVLATA (L.) Moench. — Leatherleaf. Peat bog areas; common.
- ANDROMEDA GLAUCOPHYLLA Link. — Wild rosemary. In situations similar to that of the preceding species.
- GAULTHERIA PROCUMBENS L. — Aromatic wintergreen. Mostly in dry soil along the main range.
- ARCTOSTAPHYLOS UVA-URSI (L.) Spreng. var. COACTILIS Fernald & McBride (see *Rhodora*, 16: 212. 1914). — Bearberry. Exposed ground, especially along the main range; frequent. Collected by Dr. N. L. Fassett.
- EPIGAEA REPENS L. — Trailing arbutus. Along the main range and on Government Peak.
- CHIOGENES HISPIDULA (L.) T. & G. — Creeping snowberry. Woodlands in low ground.
- VACCINIUM PENNSYLVANICUM Lam. — Early upland blueberry. Dry soil on main ridge; common. Some variation in the color of the berries was noticed, but these may represent merely forms of the species.
- VACCINIUM CANADENSE Kalm. — Sourtop. Low ground.

68. PRIMULACEAE (Primrose Family)

- LYSIMACHIA TERRESTRIS (L.) BSP. — Yellow loosestrife. Low open ground; common.
- LYSIMACHIA THYRSIFLORA L. — Tufted loosestrife. Low ground; occasional.
- STEIRONEMA CILIATUM (L.) Raf. — Fringed loosestrife. Wet ground; frequent.
- STEIRONEMA LANCEOLATUM (Walt.) Gray. — Low ground; occasional.
- TRIENTALIS BOREALIS Raf. (*T. americana* of authors. See *Rhodora*, 11:236. 1909). — Starflower. Low ground in the hemlock climax; frequent.

69. OLEACEAE (Olive Family)

- FRAXINUS AMERICANA L. — White ash. In the climax maple forest; occasional.
- FRAXINUS NIGRA Marsh. — Black ash. Common in the flood plain of Carp River. The basal portion of this tree can apparently be covered with water for some time without injury.

70. GENTIANACEAE (Gentian Family)

- HALENIA DEFLEXA (Sm.) Griseb. — Spurred gentian. Upper reaches of Carp River. Probably not common.
- MENYANTHES TRIFOLIATA L. var. MINOR Michx. (*M. trifoliata* of *Gray's Manual*. See *Rhodora*, 31:195. 1929). — Buckbean. Wet open ground bordering Carp River; occasional.

71. APOCYNACEAE (Dogbane Family)

- APOCYNUM ANDROSAEMIFOLIUM L. — Spreading dogbane. In rather dry soil along summit of main range; frequent.
- APOCYNUM CANNABINUM L. — Indian hemp. Collected on bluffs above Carp Lake.

72. ASCLEPIADACEAE (Milkweed Family)

- ASCLEPIAS PHYTOLACCOIDES Pursh. — Poke milkweed. On talus slope of main range; apparently rare.
- ASCLEPIAS INCARNATA L. — Swamp milkweed. Low wet ground; frequent.

73. CONVULVULACEAE (Morning-Glory Family)

CONVOLVULUS SPITHAMAEUS L. — Low bindweed. Dry soil along summit of range; common.

74. BORAGINACEAE (Borage Family)

CYNOGLOSSUM OFFICINALE L. — Hound's tongue. Occasional as an introduction.

CYNOGLOSSUM BOREALE Fernald. — Wild comfrey. Talus slope of main range; occasional.

MERTENSIA PANICULATA (Ait.) G. Don. var. SUBCORDATA (Greene) Macbr. — For the identification of this variety the writer is indebted to I. M. Johnston, to whom Dr. M. L. Fernald kindly submitted it. Tall lungwort. Swampy ground along woodland streams; occasional.

75. VERBENACEAE (Vervain Family)

VERBENA URTICAEFOLIA L. — White vervain. Open ground; occasional.

VERBENA HASTATA L. — Blue vervain. Flood plain of Carp River; common.

76. LABIATAE (Mint Family)

SCUTELLARIA LATERIFLORA L. — Skullcap. Low ground; frequent.

SCUTELLARIA EPILOBIIFOLIA Hamil. (*S. galericulata* of Gray's *Manual*. See *Rhodora*, 23: 85. 1921).

NEPETA CATARIA L. — Catnip. Introduced around camp sites; occasional.

PRUNELLA VULGARIS L. — Selfheal. Moist to dry soil, usually in open ground; occasional.

GALEOPSIS TETRAHIT L. var. BIFIDA (Boenn.) Lej. & Court. (*G. Tetrahit* of authors. See *Rhodora*, 12: 141. 1910). — Hemp nettle. This introduced plant was found in the flood plain of Carp River.

BLEPHILIA HIRSUTA (Pursh) Benth. — Wood mint. Low ground; occasional.

SATUREJA VULGARIS (L.) Fritsch. — Field basil. Dry soil along summit of range; common.

LYCOPUS UNIFLORUS Michx. — Northern bugleweed. Low ground; occasional.

LYCOPUS AMERICANUS Muhl. — Water horehound. Low ground; occasional.

MENTHA ARVENSIS L. var. CANADENSIS (L). Briq. — American wild mint. Low wet ground; common.

77. SOLANACEAE (Nightshade Family)

SOLANUM NIGRUM L. — Nightshade. Open ground or along wood roads; occasional.

PHYSALIS HETEROPHYLLA Nees. — Open ground in sandy soil; occasional. Ground cherry.

78. SCROPHULARIACEAE (Figwort Family)

VERBASCUM THAPSUS L. — Common mullein. Introduced in places; occasional.

SCROPHULARIA LANCEOLATA Pursh (*S. leporella* of *Gray's Manual*. See *Torrey*, 22:82. 1922). — Figwort. Moist ground; occasional.

CHELONE GLABRA L. — Turtlehead. Low ground; occasional.

MIMULUS RINGENS L. — Monkey flower. Bordering water courses; occasional.

VERONICA SERPYLLIFOLIA L. — Thyme-leaved speedwell. Along wood roads, where it is probably introduced.

MELAMPYRUM LINEARE Lam. — Cow wheat. Dry soil on gravelly slopes; frequent.

79. OROBANCHACEAE (Broom-Rape Family)

CONOPHOLIS AMERICANA (L. f.) Wallr. — Cancerroot. Woods bordering Carp Lake; frequent.

80. LENTIBULARIACEAE (Bladderwort Family)

UTRICULARIA VULGARIS L. var. AMERICANA Gray. — Greater bladderwort. Common in Carp River.

UTRICULARIA CORNUTA Michx. — Horned bladderwort. Lake shores.

81. PLANTAGINACEAE (Plantain Family)

PLANTAGO MAJOR L. — Plantain. Open ground; occasional.

PLANTAGO RUGELLII Dcne. — Plantain. This species and the one preceding both have the appearance of having been introduced into the region.

PLANTAGO LANCEOLATA L. — English plantain. Introduced in places.

82. RUBIACEAE (Madder Family)

- GALIUM LANCEOLATUM* Torr. — Wild licorice. Gravelly soil along main range.
- GALIUM APARINE* L. var. *VAILLANTII* (DC.) Koch. — Cleavers. Moist woodlands.
- GALIUM TRIFLORUM* Michx. — Sweet-scented bedstraw. Low ground in woods; common.
- GALIUM ASPRELLUM* Michx. — Rough bedstraw.
- GALIUM CLAYTONI* Michx. — Low ground, Carp Lake Valley.
- MITCHELLA REPENS* L. — Partridgeberry. Woodlands, in rather dry soil; occasional.

83. CAPRIFOLIACEAE (Honeysuckle Family)

- DIERVILLA LONICERA* Mill. — Bush honeysuckle. Dry ground; common on the talus slopes.
- LONICERA CANADENSIS* Marsh. — American fly honeysuckle. Woodlands; frequent.
- LONICERA OBLONGIFOLIA* (Goldie) Hook. — Swamp fly honeysuckle. "In the shrub zone of the tamarack swamp" (Ruthven, 7).
- LONICERA DIOICA* L. var. *GLAUDESCENS* (Rydb.) Britton. — On talus slopes and along the shore of Lake Superior. *Lonicera prolifera* (Kirchner) Rehder reported by N. C. Fassett in 1929.
- SYMPHORICARPOS ALBUS* (L.) Blake (includes *S. racemosus* Michx. var. *pauciflorus* Robbins, the form occurring here. See *Rhodora*, 16: 118. 1914).
- LINNAEA BOREALIS* L. var. *AMERICANA* (Forbes) Rehder. — Twin-flower. Moist woodlands.
- TRIOSTEUM PERFOLIATUM* L. var. *AURANTIACUM* (Bicknell) Wiegand. — Feverwort. Woodlands; occasional.
- VIBURNUM OPULUS* L. var. *AMERICANUM* (Mill.) Ait. — Highbush cranberry. Low ground; occasional.
- VIBURNUM* affine Bush var. *HYPOMALACUM* Blake (*V. pubescens* of *Gray's Manual*. See *Rhodora*, 20: 11. 1918). — Dry soil along main ridge.
- VIBURNUM DENTATUM* L. — Arrowwood. On rocky outcrops.
- VIBURNUM CASSINOIDES* L. — Black haw. Low ground; occasional.
- SAMBUCUS RACEMOSA* L. — Red-berried elder. Very common in wind-falls and "burns."

84. CAMPANULACEAE (Bluebell Family)

CAMPANULA ROTUNDIFOLIA L. — Harebell. In rock crevices both inland and along the Lake Superior shore; frequent.

CAMPANULA ULIGINOSA Rydb. — Marsh bellflower. Low ground; occasional.

85. LOBELIACEAE (Lobelia Family)

LOBELIA INFLATA L. — Indian tobacco. Rather dry ground; occasional.

LOBELIA KALMII L. — Rock crevices along Lake Superior shore; common.

86. COMPOSITAE (Composite Family)

EUPATORIUM MACULATUM L. (*E. purpureum* var. *maculatum* of Gray's Manual. See *Rhodora*, 22:57. 1920). — Joe-pye weed. Low ground; frequent.

EUPATORIUM PERFOLIATUM L. — Boneset. Flood-plain areas.

SOLIDAGO FLEXICAULIS L. (*S. latifolia* of Gray's Manual. See Mackenzie, *Rhodora*, 30:223-224. 1928). — Broad-leaved goldenrod. In maple woods; frequent.

SOLIDAGO HUMILIS Pursh (*S. uliginosa* of Gray's Manual. See *Rhodora*, 17:6. 1915). — Swamps in vicinity of Little Carp Lake.

SOLIDAGO HISPIDA Muhl. — Summit of main range and rock crevices along Lake Superior shore; occasional.

SOLIDAGO RANDII (Porter) Britton. — Mostly along summit of main range. This was reported by the writer in Part I, p. 42, as var. *monticola* Porter.

SOLIDAGO JUNCEA Ait. — Early goldenrod. Along summit of main range and rock crevices along Lake Superior shore; occasional.

SOLIDAGO SEROTINA Ait. — Late goldenrod. Low ground.

SOLIDAGO HIRSUTISSIMA Mill. (*S. altissima* L. of Gray's Manual. See Mackenzie, *Rhodora*, 29:72-75. 1927).

SOLIDAGO CANADENSIS L. — Damp open ground; occasional.

SOLIDAGO GRAMINIFOLIA (L.) Salisb. — Among slopes of main range.

ASTER MACROPHYLLUS L. — Semiopen ground in maple woods; frequent.

ASTER LOWRIEANUS Porter. — Vicinity of Little Carp Lake.

ASTER POLYPHYLLUS L. (*Aster Faxoni* Porter). — Rock crevices along Lake Superior shore.

- ASTER PUNICEUS Ait. — Purple-stem aster. Low ground; frequent.
- ASTER LATERIFLORUS (L.) Britton. — Borders of woodlands; frequent.
- ASTER UMBELLATUS Mill. — Flat-top aster. Lake shores; frequent.
- ASTER TRADESCANTI L. — Low ground, Carp River Valley. *A. paniculatus* was included in Part I, but a more careful study of the material seems to indicate that it represents *A. Tradescanti*, as that plant is understood.
- ERIGERON PHILADELPHICUS L. — Along wood road from Union Bay.
- ERIGERON RAMOSUS (Walt.) BSP. — Daisy fleabane. Along summit of range.
- ERIGERON ANNUUS (L.) Pers. — Along wood roads; occasional.
- ERIGERON CANADENSIS L. — Horseweed. Very common in "burns."
- ANTENNARIA NEODIOICA Greene. — Dry open ground along summit of range.
- ANAPHALIS MARGARITACEA (L.) Benth. & Hook. — Pearly everlasting. Frequent on burned areas.
- GNAPHALIUM DECURRENS Ives. — Clammy everlasting. Dry soil; occasional.
- GNAPHALIUM ULIGINOSUM L. — Low cudweed. Seen at Union Bay.
- ADENOCAULON BICOLOR Hook. — Moist woodlands; frequent. Not a rare plant in the Upper Peninsula.
- RUDBECKIA HIRTA L. — Black-eyed Susan. Dry ground; occasional.
- HELIANTHUS SCABERRIMUS Ell. — In burned areas. Specimen identified by Dr. E. E. Watson.
- HELIANTHUS GIGANTEUS L. — Open woodlands near summit of range.
- BIDENS BECKII Torr. — Water marigold. In Carp River; occasional.
- HELENIUM ALTISSIMUM Link. (*H. autumnale* of *Gray's Manual*). — Sneezeweed. Low ground; occasional.
- ACHILLEA MILLEFOLIUM L. — Yarrow. Along roads and trails; occasional.
- ANTHEMIS COTULA L. — Dog fennel. Along wood roads.
- CHRYSANTHEMUM LEUCANTHEMUM L. — Oxeye daisy. Probably the var. *pinnatifidum* Lecoq. & Lamotte. No specimen retained.
- ARTEMISIA CAUDATA Michx. — Summit of main range.
- ERECHTITES HIERACIFOLIA (L.) Raf. — Fireweed. Border of maple woods; occasional.
- SENECIO PAUPERculus Michx. — Balsam groundsel. Rock crevices along Lake Superior shore.

- ARCTIUM MINUS (Hill.) Bernh. — Common burdock. Around neglected camp sites.
- CIRSIUM LANCEOLATUM (L.) Hill. — Bull thistle. Old camp sites; occasional.
- CIRSIUM MUTICUM Michx. — Swamp thistle. Low ground in woods; occasional.
- CIRSIUM ARVENSE (L.) Scop. — Canada thistle. Wood roads and trails.
- TARAXACUM OFFICINALE Weber. — Dr. M. L. Fernald has shown that this plant should now be called *Taraxacum palustre* (Lyons) Lam. & DC. var. *vulgare* (Lam.) Fernald, if the International Rules of Nomenclature be strictly applied. (See *Rhodora*, 35 : 380. 1933.) Pending further nomenclatorial adjustments or more extended usage of this name, the writer has preferred to use the older name. Common dandelion. Introduced in places.
- SONCHUS OLERACEUS L. — Annual sow thistle. Introduced in places.
- SONCHUS ARVENSIS L. — Field sow thistle. Sparingly introduced.
- LACTUCA HIRSUTA Muhl. — Dry soil on main range.
- LACTUCA CANADENSIS L. — Tall yellow lettuce. Occasional, especially on "burns."
- LACTUCA SPICATA (Lam.) Hitchc. — Tall blue lettuce. On "burns"; frequent.
- PRENANTHES ALBA L. — Rattlesnake root. In climax maple forests; occasional.
- HIERACIUM SCABRUM Michx. — Dry soil along summit of range.
- HIERACIUM SCABRUM Michx. var. *TONSUM* Fern. & St. John. — Collected by N. C. Fassett in 1929.
- HIERACIUM CANADENSE Michx. — Hawkweed. Along Lake Superior shore.

MICHIGAN STATE COLLEGE
EAST LANSING, MICHIGAN

LITERATURE

1. BEAL, W. J. 1903. Michigan Flora, a List of the Fern and Seed Plants Growing without Cultivation. Ann. Rep. Mich. Acad. Sci., 5 : 1-147.
2. BRITTON, N. L., AND BROWN, A. 1913. An Illustrated Flora of the Northern United States, Canada and the British Possessions. In three volumes. Edition 2.
3. DARLINGTON, H. T. 1920, 1923. Contribution to the Flora of Gogebic

- County, Michigan. *Ann. Rep. Mich. Acad. Sci.*, 22: 147-176; *Pap. Mich. Acad. Sci., Arts and Letters*, 1 (1921) : 74-82.
4. DARLINGTON, H. T. 1931. Vegetation of the Porcupine Mountains, Northern Michigan. Part I. Ecology. *Pap. Mich. Acad. Sci., Arts and Letters*, 13 (1930) : 9-65.
 5. JACKSON, C. T. 1849-50. Senate Documents, 1st Sess. 31st Cong., Vol. 3. Washington, D. C.
 6. ROBINSON, B. L., AND FERNALD, M. L. 1908. *Gray's New Manual of Botany*, Seventh Edition. New York.
 7. RUTHVEN, A. G. 1906. Notes on the Plants of the Porcupine Mountains and Isle Royale, Michigan. Pp. 86-92 in *An Ecological Survey in Northern Michigan*. A Report from the University Museum, published by the State Board of Geological Survey as part of the Report for 1905.
 8. WIEGAND, K. M., AND EAMES, A. J. 1926. The Flora of the Cayuga Lake Basin, New York. Cornell University Agric. Exper. Station, Memoir 92.

PLATE V



FIG. 1. Shore line of Lake Superior, looking west; slope at left rises to the main range; timber along shore burned two years previously; bedding planes of rocks clearly shown



FIG. 2. South side of first range from Carp Lake. The deciduous forest forms a fringe in the foreground. Above this is a steep slope of talus material, whose lower portion is occupied by white and upper portion by red pines



FIG. 1. A ground cover typical of cedar swamps, Carp River Valley; the plant in the foreground is *Habenaria hyperborea*; other plants in the area are *Circaea alpina*, *Aralia nudicaulis*, *Clintonia borealis*, *Thelypteris cristata*, and *Thelypteris spinulosa* var. *intermedia*



FIG. 2. View of escarpment, first range, looking north from Carp River Valley; a narrow fringe of deciduous forest can be seen at the base of the slope; the trees higher up the slope consist mostly of white and red pines. The floor of the valley at this point represents an old "stamp-sand" area

GROWTH RESPONSES OF VARIOUS PLANTS TO INDOLE 3-N-PROPIONIC ACID *

SAM GRANICK AND HARMAN W. DUNHAM

THIS study is a survey of the growth reactions that may be obtained from various plants when treated with indole 3-n-propionic acid. This substance, among others, has been reported by Hitchcock (2) and by Hitchcock and Zimmerman (3) to produce in a number of plants reactions similar to those produced by heteroauxin (β indole acetic acid). This is surprising in view of the fact that indole propionic acid (I.P.) was reported by Thimann and Koepfli (7) and by Kögl and Kostermans (4) to have no action on the *Avena coleoptile*. How closely the reactions obtained, by other investigators, with auxin A and heteroauxin parallel those with I.P. will become evident from our data. A further interest in a survey of this kind was the possibility that some correlations might be found between the normal growth and the regenerative abilities of cells, and their responses to I.P.

The crystalline indole-propionic acid was made up as a one per cent lanolin paste, which was applied to various parts of a plant: the upper and lower surfaces of leaf laminae, the sides of petioles, peduncles, stems, and tendrils, the cut surfaces of these organs, the surfaces of flower buds and flowers, and their longitudinally cut surfaces. Lanolin alone was applied to the control plants. No roots were treated. The plants used in this study are members of 43 genera and 24 families.

It might be expected that, because of the manner of applying the paste, none of the I.P. would penetrate into the cells, especially through thickly cuticularized surfaces. This may be the explanation for the nonreactivity of the barrel cactus or the leaves of *Sansevieria*, *Dianthus*, and *Ficus*. In the other treated plants, however, the organs were cut and the paste was applied directly to the cut sur-

* Papers from the Department of Botany of the University of Michigan, No. 558.

faces. The inability of I.P. to penetrate below the epidermis was, therefore, not the reason for the nonreactivity of various plants.

EXPERIMENTAL RESULTS

Even after three weeks I.P. appeared to have no effect on the flowers and the flower buds of *Chrysanthemum* sp., *Cosmos sulphureus*, *Cucumis sativus*, *Cucurbita pepo*, Dwarf Cosmos, *Impatiens balsameae*, *Mimosa pudica*, *Nicotiana tabacum*, and *Salpiglossus sinuata*. No microscopic examinations of these organs were made. The cucumber fruit was apparently stimulated; lack of material, however, prevented a confirmation of this observation.

The tendrils of Cucurbita, Sweet Pea, Schizobasopsis, and Gloriosa showed no bending reactions with I.P. Weaker preparations of I.P., applied to Sweet Pea tendrils of various ages, likewise did not produce any growth responses. The cut surfaces of the tendrils of the cucurbits which had been treated with the paste showed slight swellings on the cut areas thirteen days afterward. The reactions of the other organs are set forth in the accompanying table. These organs are young or relatively new growths.

The symbols and terms used in the table have the following meanings:

- 0 No reaction observed;
- Negative * bending, that is, bending occurred away from the side on which I.P. had been applied;
- + Positive * bending, that is, bending occurred toward the side on which I.P. had been applied;
- "Down," "up." Reaction of petioles by bending in the designated manner, no matter where paste has been applied;
- "Rapid," "medium," "slow." Length of time that elapsed before a reaction was observable. (A "rapid" reaction occurred within two days; a "medium" reaction occurred within five to ten days.)

Unless otherwise noted the designated effects occurred only at the places treated with the lanolin-indole propionic-acid paste.

The numbers in parentheses in the stub of the table refer to notes that follow the table.

Besides the experiments on seed plants two species of green algae and a species of fern were also investigated. *Chlorella pyrenoidosa* and *Cystococcus coherens* were used in pure culture. These species were grown in 12 per cent Shive's solution in 100 c.c. Erlenmeyer flasks. Five flasks of each species served as controls. The other

* This term has been used by Zimmerman and Wilcoxon (8).

TABLE I

GROWTH RESPONSES TO INDOLE 3-N-PROPIONIC ACID

(Symbols and terms used in this table are explained on page 70.)

Name of plant	Age	Petiole			Peduncle			Leaf lamina		Stem		Other reactions
		Bending	Reactivity	Other reactions	Bending	Reactivity	Other reactions	Bending	Reactivity	Bending	Reactivity	
MARILLIACEAE												
Marsilia quadrifolia.....	young	—	.....	.....	..	.....	.....	0	.....	..	.....	.....
SELAGINELLACEAE												
Selaginella Kraussiana.....	mature	.....	.....	.....	..	.....	.....	.....	.....	—	medium	.....
ARACEAE												
Zantedeschia aethiopica (1) .	mature	down	rapid	.....	—	medium	.....	—	slight	..	.....	.....
GRAMINEAE												
Avena sativa.....	50 cm.	.....	.....	.....	.....	.....	.....	0	.....	0	.....	.....
Zea Mays (2).....	25–40 cm.	.....	.....	.....	.....	.....	.....	0	.....	0	.....	.....
Andropogon Sorghum.....	30 cm.	.....	.....	.....	.....	.....	.....	0	.....	0	.....	.....
COMMELINACEAE												
Commelina benghalensis...	mature	0	.....	.....	.....	.....	.....	0	.....	0	slow	slight swelling
Zebrina pendula.....	mature	0	.....	.....	.....	.....	.....	0	.....	0	slow	slight swelling
LILIACEAE												
Asparagus plumosus.....	mature	.....	.....	.....	.....	.....	.....	.....	.....	0	.....	.....
Sansevieria zebrina.....	mature	.....	.....	.....	.....	.....	.....	0	.....	..	.....	.....
Schizobasopsis volubilis	mature	.....	.....	.....	.....	.....	.....	0	.....	0	.....	.....
Gloriosa simplex.....	mature	0	.....	.....	.....	.....	.....	0	.....	0	.....	.....
AMARYLLIDACEAE												
Vallota purpurea.....	old	0	.....	.....	.....	.....	.....	0	.....	..	.....	.....
Furcraea sp.....	mature	.....	.....	.....	.....	.....	.....	0	.....	..	.....	.....

TABLE I (Concluded)
GROWTH RESPONSES TO INDOLE 3-N-PROPIONIC ACID

Name of plant	Age	Petiole			Peduncle			Leaf lamina		Stem		Other reactions	
		Bending	Reactiv- ity	Other reactions	Bending	Reactiv- ity	Other reactions	Bending	Reactiv- ity	Bending	Reactiv- ity		
FAGACEAE													
Quercus sp.	seedling	.....	.....	.....	.....	.....	.....	0	.....	0	.....	.....	
MORACEAE													
Ficus sp.	mature	.....	.....	.....	.....	.....	.....	0	.....	.....	.....	.....	
CARYOPHYLLACEAE													
Dianthus sp.	20 cm.	.....	.....	.....	.....	.....	.....	0	.....	.....	.....	.....	
CRASSULACEAE													
Bryophyllum calycinum (3)	mature	—	medium	.....	.....	.....	.....	0	slow	slow	slow	swelling and cell division	
Bryophyllum tubiflorum	mature	down	medium	.....	.....	.....	.....	.....	.....	.....	.....	swelling root callus swelling	
Cotyledon fulgens (4)	young	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
Kalanchoe carnea (5)	young	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
Sedum sp. (5)	young	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	
LEGUMINOSAE													
Lathyrus odoratus	mature	0	.....	.....	0	.....	.....	—	medium	—	rapid	swelling swelling	
Canavalia ensiformis (6)	young	+	slow	callus	.....	.....	.....	.....	.....	.....	.....	.....	
Phaseolus vulgaris var. Wardwell wax	seedling kidney	down	rapid	swelling	.....	.....	.....	—	rapid	—	.....	callus and periderm on hypocotyl	
Lupinus albus	seedling	down	rapid	.....	.....	.....	.....	—	rapid	—	rapid	.....	
Mimosa pudica	young and mature	.....	.....	.....	0	.....	.....	0	.....	0	.....	.....	
BALSAMINEAE													
Impatiens balsamea (7)	young and mature	down	rapid	.....	.....	.....	.....	—	medium	—	rapid	roots; cut apex swells	

GERANIACEAE									
Geranium sp.	young	.....	.....	0	.....	.....	0	.....	.....
CACTACEAE									
Perocactus Weinbergii	50 cm.	.....	.....	..	.....	.....	.....	.....	.....
PRIMULACEAE									
Cyclamen persicum	mature	—	.....	0	slow	slight swelling	—	slow	.....
APOCYNACEAE									
Vinca major	mature	0	.....	..	.....	.....	.....	.....	.....
LABIATEAE									
Coleus Blumei	young	—	slow	..	.....	.....	0	.....	slow
Coleus thyroides (8)	young	—	rapid	..	swelling	.....	0	.....	rapid
SOLANACEAE									
Salpiglossus sinuata (2 varieties)	mature	0	.....	..	.....	.....	0	.....	.....
Nicotiana tabacum	young and mature	—	medium	.....	.....	.....	—	slow and slight	.....
CUCURBITACEAE									
Cucurbita pepo (9)	mature	up	medium	swelling	±	rapid	swelling	underside only	medium
Cucumis sativus (9)	mature	up	medium	swelling	+	rapid	.....	underside only	medium
COMPOSITAE									
Chrysanthemum sp. var. Ethel Sprays	mature	0	.....	.....	—	medium	.....	.....	.....
var. Philip Rice	mature	—	medium	.....	—	medium	.....	slow	.....
Cosmos sulphureus	young	down	medium	swelling	..	.....	0	.....	medium
Cosmos sp. var. Dwarf Cosmos	young	down	slow	.....	..	.....	0	.....	slow
Rudbeckia	young	down	.....	.....	..	.....	—	medium	.....
Helianthus annuus	young	down	rapid	enlarging	..	.....	—	medium	.....

NOTES TO THE TABLE

(1) The reactions of *Zantedeschia aethiopica* to I.P. are illustrated by a series of photographs, Figures 4 A, B, C, D, Plate VII, which were taken 0, 2, 5, and 8 days, respectively, after treatment. A ring of the paste was applied around the petiole of the leaf on the right (Fig. 4A). At first this petiole bent down, but by the eighth day (Fig. 4D) was recovering its erect position. Only the outer edge of the petiole of the leaf on the left was treated, and it will be observed that the first reaction (Fig. 4B) is a slight outward bending of the petiole. Soon, however, greater elongation occurs on the outer side (Figs. 4C-D), with a consequent inward bending of the petiole. In both petioles the bending reactions have not taken place at the treated regions, but distinctly below these regions. The peduncle reacts by a lengthening of the treated side.

(2) *Zea Mays* gave no reaction when I.P. was applied directly to the nodes, by dissecting away the surrounding leaves. No reactions were observed even when slits were made into the nodes and the paste was pushed into the slits.

(3) The leaves of *Bryophyllum calycinum* were slit, on the plant, in a number of different ways, and I.P. was rubbed into the cut surfaces. Even after two months no growth reactions were observed at these cut surfaces, on either the treated or the control leaves. Examination of the stem internode, which had swelled slightly at the treated region, showed that the swelling was due to the increase in cell size of the normally small subepidermal parenchyma cells.

(4) The stem of *Cotyledon fulgens*, which had been topped at the internode and treated with I.P., after a week had become swollen for a distance of 7-8 mm. below the cut. Sections of this region showed not only that the parenchyma cells had enlarged greatly, but that these large cells had also divided. A new cell wall had been formed in the middle of the enlarged parenchyma cell, and the two nuclei of the new cells lay closely appressed on either side of this wall.

(5) The young and the mature leaves of *Kalanchoe carnea* and *Sedum sp.* were cut in different ways, and I.P. was applied to the cut surfaces. These pieces were then placed on moist filter paper in glass chambers and kept in the greenhouse. No reactions were observed even after one month. The controls seemed to fare better than the treated leaf pieces, turning brownish and flaccid less rapidly.

(6) Figure 1, Plate VII, shows the appearance of *Canavalia ensiformis* ten days after treatment. The first reaction observed when I.P. was applied to any portion of the leaf or the petiole was the downward bending of the secondary pulvinus, causing the leaf blade to lie closely appressed to the petiole. From this, one may conclude that the acid can diffuse down from the leaf into the pulvinus or can diffuse up from the petiole into the pulvinus. The bending reaction of the pulvinus was rapid, occurring within a day, in light or in darkness and returning to a normal position several days after treatment. The paste produces some callus formation when applied to the petioles, and the "positive" bending of the petiole on the right-hand side of the plant indicates an injury effect. The other petiole which was ringed with the paste exhibited no bending. The photograph also shows the result of treatment of the under side of the leaf blade, which reacted by curving upward.

Figure 2, Plate VII, illustrates the effect of the application of I.P. directly to the secondary pulvinus of *Canavalia*. Two weeks after treatment the pulvinus

had enlarged greatly and almost doubled upon itself. Its epidermis had cracked in several places and the leaf lamina was dead.

Figure 3, Plate VII, is a longitudinal section of this pulvinus. It is evident that expansion of the parenchyma cells had taken place, producing a tension great enough to tear apart the thick ring of xylem tissue. Water movement through the parenchyma tissue was apparently insufficient to supply the needs of the transpiring leaf, and the leaf gradually withered and died.

(7) *Impatiens balsameae* reacts rapidly to I.P. Treatment of the cut-stem apex produced a swelling in four days, and the original upper 10 mm. of the internode increased to 15 mm. The controls showed neither swelling nor elongation at the apex, just below the cut surface.

Figure 2, Plate VIII, shows the type of root formation produced by the I.P. paste in an atmosphere which was not very humid. The large pustules are composed of a number of roots fused together, but possessing their individual growing points. The whole mass is covered with an active periderm. The old stem, which responded to the acid, did not recover its erect position, but the stem growth after treatment responded to geotropic stimulation.

Figure 3, Plate VIII, is that of an *Impatiens* plant which was ringed with the paste at the second and the fifth internodes. It may be observed that the bending of the stem occurred below the regions of treatment. It is suggested that differential diffusion of indole propionic acid down the stem resulted in an unequal distribution of this substance, thus producing unequal growth and consequent bending. When the paste was applied to the sides of a stem, bending took place at the treated region.

(8) Figure 1, Plate VIII, is a photomicrograph of a cross section of a *Coleus thyroides* stem which had been ringed with the paste. Roots were developed on all sides. No callus was formed. The parenchyma cells enlarged greatly. The cambium was stimulated to produce more xylem and phloem. Fischnich (1) obtained similar results with *Coleus* when heteroauxin was used.

(9) In both *Cucurbita pepo* and *Cucumis sativus* the stem internodes showed swelling and whitening at the regions treated. However, white swollen patches were also observed to form along the stem, especially at the nodes. The position of these patches bore no evident relation to the areas treated with I.P.

flasks were treated in the same way as the controls, except that I.P. in the proportion of one part of the acid to a half-million parts of 12 per cent Shive's was added to the medium. The acid was dissolved in sterile nutrient solution, and the proper quantity of this was added to the sterilized nutrient solutions in the flasks. Aseptic technique was used. Examinations of the cultures have not yet been made to determine whether or not they are entirely free from contamination.

Both species of algae grew vigorously, and no difference in the amount of growth between the control and the treated cultures could be observed after forty days.

The effect of the indole propionic acid on the development of

the prothalli of *Onoclea sensibilis* was also studied. The spores were sown on 12 per cent Shive's nutrient solution in 100 c.c. Erlenmeyer flasks containing indole propionic acid in the proportion of one part to a half-million parts of nutrient solution.

Onoclea showed a definitely poorer growth in the treated flasks than in the control flasks forty days after inoculation.

SUMMARY AND CONCLUSIONS

The growth reactions obtained with indole 3-n-propionic acid applied as a one per cent lanolin paste to various plant parts are similar to those reactions which have been reported by other workers (1, 2, 5, 6, 8) for heteroauxin and (5, 6) for auxin A, in inducing enlargement of parenchyma cells, cell divisions, formation of callus, stimulation of the cambium, and root formation.

A study of bending and cell elongation of various structures indicates that it is difficult to predict the direction or the degree of bending. It seems likely that the bending reactions depend on the amount of indole propionic acid that reaches the various cells, the reactivity of these cells, and the tissue tensions set up by differential growth. In some plants, for example, the leaves whose petioles had been treated bent down; in others, up; in still others the petioles themselves responded by an elongation of the region treated with the lanolin-indole propionic-acid paste.

The reactivity toward I.P. varies for the same cells under different conditions of temperature and light. In the winter, when normal growth is slow, the effect of I.P. is found to be greatly diminished. On sunny days its effect appears to be enhanced. In general, the younger and more rapidly growing organs produce rapid bending responses.

Differences in growth responses of varieties of plants were observed. For example, the small-leaved, small-flowered Ethel Sprays variety of *Chrysanthemum* reacted only slightly, whereas the large-leaved large-flowered Philip Rice variety responded more rapidly. Similarly, the smaller Dwarf Cosmos and the smaller *Coleus Blumei* reacted less markedly than did the large *Cosmos sulphureus* and the large *Coleus thyroides*.

The data, though limited to forty-three genera, indicate that the plants which belong to the same family react similarly. For example, none of the Gramineae examined (oats, corn, sorghum) gave any

growth responses to I.P. Also none of the five members of the Leguminosae used could be induced to produce roots from the stems or the petioles, although other growth reactions were manifest.

We desire to express our gratitude to Professor F. G. Gustafson for the interest shown and the advice given us throughout this investigation. We also wish to thank Professor C. D. La Rue for his suggestions and Miss Rachel Uhvits for supplying the pure cultures of algae.

UNIVERSITY OF MICHIGAN

BIBLIOGRAPHY

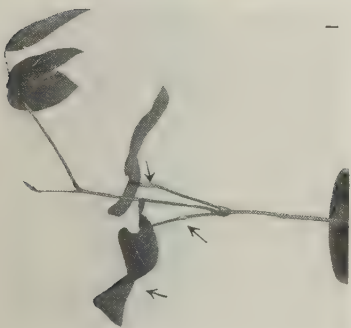
1. FISCHNICH, O. 1935. Über den Einfluss von β Indolylessigsäure auf die Blattbewegungen und die Adventivwurzelbildung von *Coleus*. *Planta*, 24: 552-583.
2. HITCHCOCK, A. E. 1935. Indole 3-n-Propionic Acid as a Growth Hormone and the Quantitative Measurement. *Contrib. Boyce Thompson Inst.*, 7: 87-95.
3. ——— AND ZIMMERMAN, P. W. 1935. Absorption and Movement of Synthetic Growth Substances from Soil as Indicated by Responses of Aerial Parts. *Ibid.*, 7: 447-476.
4. KÖGL, F., AND KOSTERMANS, D. G. 1935. Über die Konstitutions-Spezifität des Hetero-auxins. *Zeit. Physiol. Chem.*, 235: 201-216.
5. LAIBACH, F., AND FISCHNICH, O. 1935. Künstliche Wurzelbildung mittels Wuchsstoffpaste. *Ber. d. deutsch. Bot. Gesell.*, 53: 528-539.
6. SNOW, R. 1935. Activation of Cambial Growth by Pure Hormones. *New Phytologist*, 36: 347-360.
7. THIMANN, K. V., AND KOEPFLI, J. B. 1935. Identity of the Growth-promoting and Root-forming Substances of Plants. *Nature*, 135: 101.
8. ZIMMERMAN, P. W., AND WILCOXON, F. 1935. Several Chemical Growth Substances Which Cause Initiation of Roots and Other Responses in Plants. *Contrib. Boyce Thompson Inst.*, 7: 209-230.

EXPLANATION OF PLATES VII-VIII

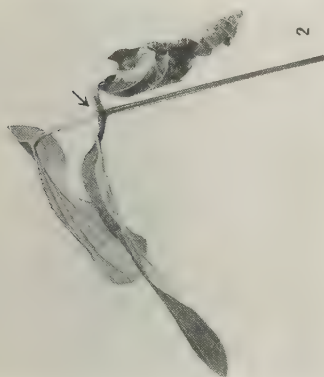
Growth responses to indole 3-n-propionic acid. The arrows indicate the region of application of I.P. paste.

PLATE VII

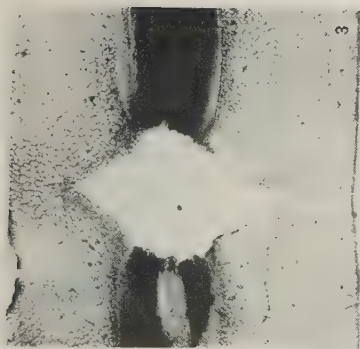
- FIG. 1. Reactions of the petioles and the leaves of *Canavalia ensiformis*
FIG. 2. Reaction of the secondary pulvinus of *C. ensiformis*
FIG. 3. Longitudinal section of the secondary pulvinus of *C. ensiformis*, showing rupture of vascular bundle
FIG. 4 A, B, C, D. Successive growth responses of *Zantedeschia aethiopica* 0, 2, 5, and 8 days, respectively, after treatment with I.P. paste



1



2



3



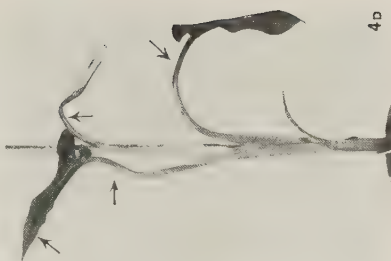
4A



4B



4C



4D

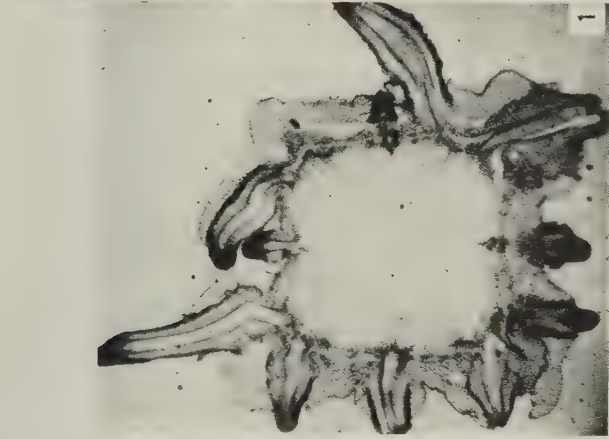


FIG. 1. Cross section of the stem of *Coleus thyroides* which had been ringed with lanolin I.P. paste
 FIG. 2. Root formation on the stem of *Impatiens balsameae* treated with I.P. paste
 FIG. 3. Bending of *I. balsameae*, caused by differential diffusion of I.P.

PROLIFERATION AND RENEWAL OF GROWTH IN SUPPRESSED FRUITS IN TOMATOES *

FELIX G. GUSTAFSON

DURING the summer of 1934 it was noticed that tomato plants which had most of their leaves removed produced several buds in each leaf axil. Proliferations were also produced from the cut end of the stem and, in a few instances, even from the midrib of old leaves. Since the experiment in which these proliferations had been noticed was repeated during the summer of 1935, it seemed profitable to make further observations. In these experiments the plants were pruned to about two-foot lengths with one, two, three, or four leaves per plant.

During the whole summer after the pruning, it was necessary at frequent intervals to remove buds from the leaf axils; each axil produced a number of such growths, one after another. The cut surface of the end of the stem also produced numerous shoots, as shown in Plate IX, Figures 1-2, and Plate X, Figure 2. Many times a ring of such shoots would appear clear around the stem and, unless removed, would grow into a compact cluster of stems, as shown in Plate IX, Figure 2. Repeated cutting always produced new proliferations. There is no question that the whole of the old shoot was completely removed each time and that new ones were produced from the cells of the stem either from the cambium or from some other cells. No anatomical studies were made.

Toward the end of the summer proliferations appeared in two other places on the plants. These were not nearly so common as the ones previously mentioned, but still there were a number of plants that showed them. In some of the older leaves new growths appeared from the midrib near the leaflets. No proliferations ever made their appearance except close to a leaflet. Several shoots (Pl. X, Fig. 1) were usually produced by each leaf and, if permitted to develop,

* Papers from the Department of Botany of the University of Michigan. No. 583.

grew into sizable stems. After several fruits had been produced and had matured in a fruiting cluster many such fruiting stems showed renewed growth, either in the form of renewed flower formation, as in Plate X, Figure 2, or in the extension of the fruiting branch into a leafy branch which eventually produced flowers and fruits (Pl. XI, Fig. 1). In some plants such a fruiting branch produced both additional flowers and a leafy shoot (Pl. XI, Fig. 2).

These proliferations are of considerable interest to the writer because they show such a persistence in vegetative growth. When the growing point of the plant is removed, there is at once the formation of lateral shoots from the axils of leaves; when these shoots are removed more are formed, and even the cut end of the stem begins to proliferate. If these outlets are all suppressed, some plants will then find an outlet for this tendency to vegetativeness in the leaves or in the old fruiting stems, which have already produced a crop of fruits.

There cannot be any question about the formation of these shoots from cells already differentiated, at least in the old leaves, where there is no cambium, and it seems that the same thing is probably true with respect to the fruiting stems also. In the case of the shoots formed from the axils of the leaves and the cut surface of the stems, cambium probably gives rise to the new growths.

It seems to the writer that in plants which have been decapitated and have had new shoots removed repeatedly there must be an accumulation of growth hormones of one sort or another which, having no outlet, finally bring about the renewal of cell division in such structures as the leaf and the fruiting stem. Since little is known of the action of growth hormones on cambial cells, it is useless to speculate on how the hormone might act on these cells.

Besides the proliferations mentioned, another peculiarity was observed in these plants. It sometimes happens that a flower which has all the appearance of having completed the process of fertilization does not develop a fruit. The corolla is dropped and the calyx and the ovary remain in the cluster, but no development takes place. If there is no development within a week or two after blossoming, there usually will be none later on. However, it was noticed that in about 50 per cent of the plants which were pruned to one, two, three, or four leaves and had the top cut off, suppressed fruits began to grow after the others on the plant had matured and been removed.

Sometimes these belated fruits grew to normal size, but frequently they grew only a little and then matured.

What is the explanation for this renewal of growth in a structure which had long since stopped growing? And why did these fruits stop growing in the first place? The fact that they later developed indicates that fertilization must have taken place in them at the same time that it took place in the others, which developed at once. Yet there was no enlargement of either the ovules or the ovaries until about two months later. Did these fruits for some reason or other fail to get a start at the right time and were they later inhibited by the others which did make the proper start, either because of lack of food or because of the production of inhibiting substances by the growing fruits? From the facts that each plant which produced these delayed fruits had already matured from two to four fruits and had a very restricted leaf surface, it would seem that the food supply was the cause of the suppression. But, on the other hand, these same plants were constantly using food in the production of new shoots in out-of-the-way places. It seems, therefore, more likely that the suppression was due to the production of inhibiting substances by the developing fruits, and that when these were removed the growth was renewed as a consequence of the presence in abundance of the proper growth hormones.

It may, then, be considered that, when the suppressing influence of the apical growing point is eliminated by the removal of the top of the tomato plant, the growth hormones, which are produced in the leaves, activate the cambial cells in the stem, at the cut surface and in the leaf axils, to renewed growth; and even the parenchyma cells of the midrib of a leaf may be caused to form new cells which differentiate into shoots. With respect to fruits, as just mentioned, the suppression of some of them may be thought of as due to the action of inhibiting substances produced by the developing fruits; and when the latter are matured the growth hormones bring about a renewal of growth processes in the suppressed fruits. The writer has never noticed this late development of fruits in plants which have not had their growth zones removed. In these experimental plants it is likely that there is an overabundance of growth hormones, due to absence of growing regions other than cambium, and this results in these unusual growths.

PLATES IX-XI



FIG. 1. Shoots produced from the cut surface of the stem of a tomato vine



FIG. 2. Large and numerous shoots produced from the cut surface of the stem; also shoots coming from the midrib of an old leaf



FIG. 1. Large shoots growing out of the midrib of an old tomato leaf



FIG. 2. Second flowering of cluster which had matured three fruits; also shoot from end of stem



FIG. 1. Large shoot produced by a flower cluster after it had matured several fruits



FIG. 2. Flower clusters producing both flowers and vegetative shoots

WHEN DOES A PINE TREE COMPLETE ITS SEASONAL GROWTH? *

FELIX G. GUSTAFSON

SEVERAL years ago the question was raised, in a conversation: When is growth of a tree in height and in diameter completed for the growing season? At the time the writer was conducting an experiment on growth of young *Pinus sylvestris* trees, about 1.3 meters in height, and it seemed to be a good opportunity to answer the query. Seventy-eight trees from a stand growing on the north slope of a sandy loam hill were used in the experiment. On May 25 the first measurement of the season was made. At that time the trees had made a height growth on an average of 33.8 cm. since September 28 the preceding fall, when they were last measured. As the new growth was at breast height, it was used for the study of diameter growth. It probably was not so good as an older portion of the stem would have been, but because of a desire to begin diameter measurements at that height in future experiments, the decision was made to use the new growths in spite of this possible drawback. In the second year, this objection was not present. Measurements could not be continued throughout the second season because the writer was going to be away for the fall and early winter.

The graph (Fig. 2) shows that the terminal growth is very rapid and is, for practical purposes, completed by the end of June. From the fact that the cells concerned in the apical elongation are formed during the preceding season and that elongation consists essentially of an enlargement and a differentiation of these cells, one would expect the growth to be rapid and completed early during the growing season. On the other hand, the lateral or diameter growth continues much later into the summer, probably being completed by the end of August. The commencement is doubtless later than that of elongation. Certainly the time of maximum rate of growth is later than that for height growth.

* Papers from the Department of Botany of the University of Michigan, No. 582.

It would be interesting to know whether the lateral growth is dependent upon stored food or upon food manufactured during the

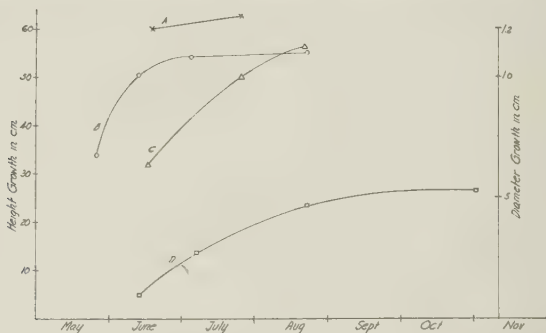


FIG. 2. Graph showing growth of *Pinus sylvestris*. Because the time at which growth began each year is not known the curves have not been started at the base line, but rather at the point where the first measurement was made for the year. In the spring of 1935 *Pinus sylvestris* trees grown on the campus showed the first signs of elongation on April 25, and trees on a north slope would be somewhat later. As a result one may consider that there would have been little or no growth before the first of May. Curves A and B represent growth in height: B for the summer of 1930 and A for that of 1931. Curves C and D represent the diameter growth: D for the summer of 1930 and C for that of 1931.

season in which growth takes place. This question might be answered by studying deciduous as well as coniferous trees.

This work was done at Stinchfield Forest, property of the School of Forestry and Conservation, University of Michigan, and the writer takes this opportunity of expressing his appreciation for the facilities placed at his disposal.

UNIVERSITY OF MICHIGAN

ADDITIONS TO THE FLORA OF CHIPPEWA COUNTY, MICHIGAN *

FREDERICK J. HERMANN

THE *Miscellaneous Papers on the Botany of Michigan* of C. K. Dodge¹ includes, as the third paper, an account of the flora of Chippewa County entitled "Observations on the Wild Plants at Whitefish Point and Vermilion, near the South Shore of Lake Superior, and Other Parts of Chippewa County, Michigan, in 1914." The usual care and discrimination of the author are evident in this conscientiously annotated list, and it must serve as the basis for any more detailed work upon the flora of the county as a whole which may be undertaken in the future. The topography and the vegetation of the county are sufficiently varied to make it floristically one of the most interesting in the state, so that it would justify a more intensive study than it has heretofore received. An annotated list of species not reported by Dodge is here offered as a small contribution to a further knowledge of the flora of the county.

This list is based upon a part of the collections made by the writer on Sugar Island, which is in the St. Mary's River south and east of Sault Sainte Marie, and represents the eastern extremity of the county. The majority of the collections are from the Chase S. Osborn Preserve near the southern end of the island, a tract of some three thousand acres which the University of Michigan received as a gift from the Honorable Chase S. Osborn in 1929. Through the kindness of Professor W. F. Ramsdell, who is in charge of the Preserve, I spent there the first two weeks of September, 1935, with headquarters at the cabin which was included in the gift and which offered ideal facilities for the preparation of specimens.

A brief account of the vegetation of Sugar Island has been pub-

* Papers from the Department of Botany and the Herbarium of the University of Michigan, No. 574.

¹ Publication 31, Biological Series 6, Michigan Geological and Biological Survey, Lansing, 1921.

lished by Dr. W. C. Steere in the introduction to his paper, "The Bryophytes of the Chase S. Osborn Preserve of the University of Michigan, Sugar Island, Chippewa County, Michigan."² It will suffice here to state that the southern part of the island is densely wooded, the higher ridges being covered with maple forest. The more extensive areas of low woods are mixed forest of unusually heterogenous composition. Here pine, birch, maple, poplar, arbor vitae, balsam, and white spruce are plentiful, and several tamarack-black spruce bogs also are found. Much of the shore line is rocky, but along the lower sandy beaches marshes are frequent. There is, then, ample variety of plant habitats, and a study of the vascular flora earlier in the season would doubtless reveal many additional species which are not yet known from the county.

As a means of reference the writer's collection numbers are included in the following annotated list. Distances, unless otherwise specified, are measured from Homestead, the only settlement at the southern end of the island.

LIST OF SPECIES

- EQUISETUM PALUSTRE L. — Plentiful on the flooded, sandy shore of St. Joseph Channel, one-half mile south, 7197.
- LYCOPodium ANNOTINUM L. var. ACRIFOLIUM Fernald. — Low spruce-birch woods, 1 mile northwest, 7043.
- ISOËTES ECHINOSPORA Dur. var. BRAUNII (Dur.) Engelm. — Wet, sandy shore of Lake George, 1½ miles northwest, 7020; marshy edge of Duck Lake, 1¾ miles northwest, 7156.
- POTAMOGETON ALPINUS Balbis. — Lake George, near shore, 1½ miles northwest, 7230.
- POTAMOGETON FILIFORMIS Pers. var. BOREALIS (Raf.) St. John. — Lake George, near shore, 1½ miles northwest, 7302.
- POTAMOGETON FOLIOSUS Raf. var. MACELLUS Fernald. — Channel between Neebish Island and Sugar Island, near shore, 1½ miles southwest, 7236.
- POTAMOGETON RICHARDSONII (Benn.) Rydb. — Lake George, near shore, 1½ miles northwest, 7153, 7224.
- POTAMOGETON ROBBINSII Oakes. — Lake George, near shore, 1½ miles northwest, 7231.

² *American Midland Naturalist*, 15: 761-769. 1934.

- POTAMOGETON ZOSTERIFORMIS Fernald. — Lake George, in 6 feet of water, $1\frac{1}{2}$ miles northwest, 7225.
- SAGITTARIA GRAMINEA Michx. — Lake George, near shore, $1\frac{1}{2}$ miles northwest, 7229.
- GLYCERIA BOREALIS (Nash) Batchelder. — In shallow water near shore of Lake George, $1\frac{1}{2}$ miles northwest, 7026.
- AGROPYRON TRACHYCAULON (Link.) Steud. var. NOVAE-ANGLIAE (Scribn.) Fernald. — Common in dry, rocky, pine-maple-birch woods, $1\frac{1}{2}$ miles northwest, 7105.
- ELEOCHARIS OBTUSA (Willd.) Schultes. — Frequent. Wet, sandy shore of Lake George, $1\frac{1}{2}$ miles northwest, 7030.
- ELEOCHARIS PAUCIFLORA (Lightf.) Link. var. FERNALDII Svenson. — Frequent. Beach pools on shore of Lake George, $1\frac{1}{2}$ miles northwest, 7140; wet, sandy shore of channel, $1\frac{1}{2}$ miles southwest, 7234.
- ELEOCHARIS SMALLII Britton. — Marsh on shore of channel, $1\frac{1}{2}$ miles southwest, 7237.
- CAREX CRINITA Lam. var. GYNANDRA (Schwein.) Schwein. & Torr. — Rocky shore of Lake George, $1\frac{1}{2}$ miles northwest, 7125.
- CAREX ROSTRATA Stokes. — Rocky shore of Lake George, $1\frac{1}{2}$ miles northwest, 7239.
- JUNCUS DUDLEYI Wiegand. — Fairly common. Low, sandy edge of Duck Lake, $2\frac{1}{4}$ miles northwest, 7087; sandy shore of Lake George, $1\frac{1}{2}$ miles northwest, 7134.
- JUNCUS EFFUSUS L. var. DECIPIENS Buchenau. — Locally common. Wet, rocky shore of Lake George, $1\frac{1}{2}$ miles northwest, 7122, 7136.
- JUNCUS NODOSUS L. — Common. Low, sandy edge of Duck Lake, $2\frac{1}{4}$ miles northwest, 7079; beach pool on shore of Lake George, $1\frac{1}{2}$ miles northwest, 7150.
- JUNCUS ALPINUS Vill. var. RARIFLORUS Hartm. — Locally plentiful. Sandy shore of Lake George, $1\frac{1}{2}$ miles northwest, 7135.
- HABENARIA OBTUSATA (Pursh) Richards. — Boggy, black spruce-birch-maple woods, 1 mile northwest, 7049.
- GOODYERA TESSELATA Lodd. — Low white spruce-birch-maple woods, 1 mile northwest, 7040.
- CORALLORRHIZA MACULATA Raf. — Occasional. Birch-maple woods, Duck Island, $2\frac{1}{4}$ miles northwest, 7098.
- POLYGONUM PUNCTATUM Ell. var. LEPTOSTACHYUM (Meisn.) Small. — Wet, sandy shore of Lake George, $1\frac{1}{2}$ miles northwest, 7024.

- RANUNCULUS REPTANS L. — Drying beach pools, shore of Lake George, $1\frac{1}{2}$ miles northwest, 7149.
- AMELANCHIER STOLONIFERA Wiegand. — Frequent on rocky slopes near shore of Lake George, $1\frac{1}{2}$ miles northwest, 7258.
- CRATAEGUS PUNCTATA Jacq. — Sandy clearing near shore of Lake George, $1\frac{1}{2}$ miles northwest, 7176.
- AGRIMONIA STRIATA Michx. — Thicket on shore of St. Mary's River, Brassar, 7209; edge of low arbor vitae-maple woods, $1\frac{1}{2}$ miles northwest, 7245.
- LATHYRUS PALUSTRIS L. var. MYRTIFOLIUS (Muhl.) Gray. — Wooded, rocky bank of Duck Lake, $2\frac{1}{4}$ miles northwest, 7090.
- GERANIUM ROBERTIANUM L. — Common on rocky shore of Duck Island, 3 miles northwest, 7094.
- RHUS TOXICODENDRON L. — Sandy clearing near shore of Lake George, $1\frac{1}{2}$ miles northwest, 7115.
- MYRIOPHYLLUM VERTICILLATUM L. — Lake George, near shore, $1\frac{1}{2}$ miles northwest, 7228.
- HYDROCOTYLE AMERICANA L. — Plentiful on wet, mossy floor of dense balsam-arbor vitae-birch woods, one-half mile south, 7199.
- OSMORRHIZA CLAYTONI (Michx.) Clarke. — Edge of low arbor vitae-maple woods, $1\frac{1}{2}$ miles northwest, 7245.
- Sium CICUTAEFOLIUM Gmelin. — Marshy edge of Duck Lake, $2\frac{1}{4}$ miles northwest, 7089.
- DAUCUS CAROTA L. — Rocky roadside, 3 miles south of Payment, 7216.
- PYROLA ELLIPTICA Nutt. — Mossy floor of dense balsam-arbor vitae-birch woods, one-half mile south, 7200.
- VACCINIUM OXYCOCCUS L. — Black spruce-tamarack bog, $1\frac{1}{4}$ miles northwest, 7190.
- ASCLEPIAS SYRIACA L. — Thicket on Rock Island, Lake George, 7196.
- CYNOGLOSSUM BOREALE Fernald. — Occasional in rocky pine-birch-maple woods near shore of Lake George, $1\frac{1}{2}$ miles northwest, 7184.
- VERBENA HASTATA L. — Frequent. Rocky shore of Duck Island, $2\frac{1}{4}$ miles northwest, 7092.
- VERONICA SERPYLLIFOLIA L. — Rocky roadside, 3 miles south of Payment, 7213.
- AGALINIS PAUPERCULA (Gray) Britton var. BOREALIS Pennell. —

Plentiful on wet, sandy shore of Lake George, $1\frac{1}{2}$ miles northwest, 7018.

UTRICULARIA MACRORHIZA Le Conte. — Stagnant pool on shore of Lake George, $1\frac{1}{2}$ miles northwest, 7227.

GALIUM PALUSTRE L. — Wet, rocky shore of Lake George, $1\frac{1}{2}$ miles northwest, 7109.

SOLIDAGO RUGOSA Mill. var. ASPERA (Ait.) Fernald. — Common on rocky and sandy shores, 7019, 7034, 7223.

SOLIDAGO SPECIOSA Nutt. — Common in low, burnt-over birch woods, $3\frac{3}{4}$ miles northwest, 7257.

ASTER MACROPHYLLUS L. var. SEJUNCTUS Burgess. — Common. Rocky pine-maple-birch woods, $1\frac{1}{2}$ miles northwest, 7119.

ASTER NEMORALIS Ait. — Locally plentiful in black spruce-tamarack bog, $3\frac{1}{4}$ miles northwest, 7219. Reported by Dodge from Emerson, Chippewa County, but, since this was the only known station for Michigan, additional localities seem worthy of record.

ASTER SAGITTIFOLIUS Wedemeyer. — Plentiful on high, grassy clearing, $1\frac{3}{4}$ miles northwest, 7249.

AMBROSIA PSILOSTACHYA DC. — Waste ground near shore of Lake Nicolet at Nine Mile Point, 5 miles south of Baie de Wasai, 7253.

BIDENS BECKII Torr. — Rare. Shallow edge of Duck Lake, $1\frac{3}{4}$ miles northwest, 7157.

ARCTIUM MINUS Bernh. — Occasional. Thicket near shore of channel, $1\frac{1}{2}$ miles southwest, 7241.

HIERACIUM AURANTIACUM L. — Gravel pit in woods, $3\frac{1}{2}$ miles southwest of Payment, 7212.

HIERACIUM SCABRUM Michx. var. TONSUM Fernald & St. John. — Clearing in sandy pine woods, 1 mile northwest, 7037.

ADDITIONS TO THE FLORA OF WASHTENAW COUNTY, MICHIGAN. II *

FREDERICK J. HERMANN

THE following list of vascular plants comprises species and varieties which apparently have not heretofore been reported as occurring in Washtenaw County, Michigan, and is supplementary to a similar list published in Volume 21 (1936) of the *Papers of the Michigan Academy of Science, Arts and Letters*. The records here listed are based upon plants collected by the writer, unless otherwise noted, during the year 1935 and preserved in his herbarium. Duplicates have been deposited in the Herbarium of the University of Michigan and specimens of most of the plants have also been rather widely distributed among the larger herbaria of the eastern states. The numbers after the locality citations are the writer's collection numbers.

Several species not previously reported in any of the published lists of the flora of Washtenaw County should be noted. These are *Thaspium barbinode* (Michx.) Nutt., *Hydrocotyle umbellata* L., and *Foeniculum vulgare* Hill, specimens of which are cited from Washtenaw County by Kenoyer,¹ and *Penstemon Digitalis* Nutt. and *Penstemon pallidus* Small, which are cited from Ann Arbor by Pennell.²

LIST OF SPECIES

CYSTOPTERIS FRAGILIS (L.) Bernh. var. MACKAYII Weatherby. —

Low beech-maple woods, $4\frac{3}{4}$ miles east of Dixboro, 6902.

BOTRYCHIUM DISSECTUM Spreng. — Low maple woods (Pawpaw Woods), 3 miles southwest of Ann Arbor, *J. H. Ehlers* 5995, and *F. J. Hermann* 7358.

* Papers from the Department of Botany and the Herbarium of the University of Michigan, No. 573.

¹ Kenoyer, L. A., "Distribution of the Umbellales in Michigan," *Pap. Mich. Acad. Sci., Arts and Letters*, Vol. 3. 1923.

² Pennell, F. W., *The Scrophulariaceae of Eastern Temperate North America*. Monograph No. 1 of the Academy of Natural Sciences of Philadelphia. 1935.

- BOTRYCHIUM DISSECTUM** Spreng. var. **OBLIQUUM** (Muhl.) Fernald. — Low maple woods (Pawpaw Woods), 3 miles southwest of Ann Arbor, *J. H. Ehlers* 5994, and *F. J. Hermann* 7359; oak-hickory-maple woods (Hickory Flats), 5 miles south of Ann Arbor, 7346½.
- EQUISETUM PALUSTRE** L. — Open, marshy bank of Huron River, 2 miles east of Ann Arbor, 7342.
- SPARGANIUM EURYCARPUM** Engelm. — Marsh, Section 1, Pittsfield Township, 4½ miles southeast of Ann Arbor, 6855.
- POTAMOGETON FILIFORMIS** Pers. var. **BOREALIS** (Raf.) St. John. — Abundant at south end of Portage Lake, 6842.
- POTAMOGETON PRAELONGUS** Wulf. — Cavanaugh Lake, 6250½.
- HIEROCHLOË ODORATA** (L.) Wahl. var. **FRAGRANS** (Willd.) Richter. — Grassy bank of Huron River (Cedar Bend) north of Ann Arbor, 6460. Typical *Hierochloë odorata* is confined to the Old World and the Rocky Mountain region.
- SCHIZACHNE PURPURASCENS** (Torr.) Swallen. — Low, rich woods east of Half Moon Lake, Section 6, Dexter Township, 6496.
- BROMUS CILIATUS** L. var. **INTONSUS** Fernald. — Swamp south of Cavanaugh Lake, 6241.
- BROMUS DUDLEYI** Fernald. — Edge of Speechley's Woods, 2¾ miles east of Ann Arbor, 6863; plentiful in swampy border of woods on south shore of Portage Lake, 6911.
- BROMUS LATIGLUMIS** (Shear) Hitchc. — Moist, open bank of Fleming Creek, 4¾ miles east of Ann Arbor, 6942; low thicket, Shanghai Pit, 3 miles northwest of Ypsilanti, 6974; wooded slope of Huron River (Cedar Bend) north of Ann Arbor, 6985.
- ELYMUS VILLOSUS** Muhl. — Abundant in small, wooded ravine on south bank of Huron River, 3 miles northwest of Ann Arbor, 6884.
- HYSTRIX PATULA** Moench. var. **BIGELOVIANA** (Fernald) Deam. — Abundant in Third Woods, 3 miles south of Ann Arbor, 6827.
- CYPERUS ERYTHORRHIZOS** Muhl. — Bank of Huron River south of Scio, 7336.
- SCIRPUS CLINTONI** Gray. — Open white oak slope, Speechley's Woods, 2¾ miles east of Ann Arbor, 6494, 6514, 6551.
- CAREX CHLOROPHILA** Mackenzie. — Gravel beach, south shore of Whitmore Lake, 7358.
- WOLFFIA COLUMBIANA** Karst. — Abundant on stagnant pools of Huron River, 2½ miles east of Ann Arbor, 6967, 6979.

- WOLFFIA PUNCTATA Griseb. — Abundant on stagnant pools of Huron River, $2\frac{1}{2}$ miles east of Ann Arbor, 6968, 6975, 7337.
- PILEA FONTANA (Lunell) Rydb. — Abundant on marshy bank of Huron River, 2 miles east of Ann Arbor, 7003, 7341.
- CHENOPODIUM BONUS-HENRICUS L. — Waste ground near Packard Road south of Ann Arbor, 6908.
- CHENOPODIUM CAPITATUM (L.) Asch. — Waste ground, University of Michigan Botanical Gardens, Ann Arbor, 6858.
- SILENE CUCUBALUS Wibel (*S. latifolia* (Mill.) Britton and Rendle). — Waste ground south of Ann Arbor, 6828.
- ARABIS LAEVIGATA (Muhl.) Poir. — Wooded slope of ravine (Cascade Glen) on south bank of Huron River, 3 miles northwest of Ann Arbor, 6539.
- FRAGARIA VESCA L. var. AMERICANA Porter. — Open grassy oak grove, Third Woods, 3 miles south of Ann Arbor, 6804.
- AMELANCHIER LAEVIS Wiegand. — Edge of low woods, Cady's Corner, $5\frac{1}{2}$ miles southeast of Ann Arbor, 6466.
- AMELANCHIER HUMILIS Wiegand. — Roadside, $1\frac{1}{2}$ miles south of Portage Lake, 6486, 6497, 6803.
- CRATAEGUS ALBICANS Ashe. — Open slope on south bank of Huron River, 3 miles northwest of Ann Arbor, 6487.
- CRATAEGUS FILIPES Ashe. — Low meadow, $3\frac{3}{4}$ miles east of Dixboro, 7347.
- CRATAEGUS MONOGYNA Jacq. — Low meadow, $3\frac{3}{4}$ miles east of Dixboro, 7346.
- GERANIUM ROBERTIANUM L. — Edge of low maple woods, $4\frac{3}{4}$ miles east of Dixboro, 6900.
- PARTHENOCISSUS VITACEA (Knerr) Hitchc. — Common. Thicket bordering Third Woods, 3 miles south of Ann Arbor, 6835; rocky railroad siding, Shanghai Pit, 3 miles northwest of Ypsilanti, 6927.
- PASTINACA SATIVA L. — Roadside, 3 miles northwest of Dexter, 6918.
- FRAXINUS LANCEOLATA Borkh. — Edge of Third Woods, 3 miles south of Ann Arbor, 6834.
- LAPPULA ECHINATA Gilibert. — Abundant in fallow field north of Saline, 6781.
- MYOSOTIS MICRANTHA Pallas. — Well established in field and along roadside, $1\frac{1}{2}$ miles south of Portage Lake, 6485; and on waste ground and cinder roadway, University of Michigan Botanical Gardens, 6508.

- DRACOCEPHALUM PARVIFLORUM Nutt. — Several plants on waste ground south of Ann Arbor, 6836.
- HYOSCYAMUS NIGER L. — Fairly common as a weed near Packard Road, south of Ann Arbor, 6819.
- CREPIS TECTORUM L. — Well established as a weed at the University of Michigan Botanical Gardens and near State Street south of Ann Arbor, 6909.
- LACTUCA SALIGNA L. — Dry, sterile soil, bank of Huron River at Shanghai Pit, 3 miles northwest of Ypsilanti, 6922, 6972.
- SONCHUS ULIGINOSUS Bieb. — Edge of marsh bordering Huron River, $3\frac{1}{4}$ miles east of Ann Arbor, 6895.
- EUPATORIUM SESSILIFOLIUM L. — Ash woods near the University of Michigan Botanical Gardens south of Ann Arbor, 7334 $\frac{1}{2}$.
- ASTER ERICOIDES L. var. PROSTRATUS (Kuntze) Blake. — Argillaceous field, $3\frac{3}{4}$ miles east of Dixboro, 7348.
- ANTENNARIA MUNDA Fernald — Grassy roadside at edge of woods, 4 miles south of Chelsea, 6533.
- ANTENNARIA PARLINII Fernald. — Wooded slope, bank of Huron River west of Pontiac Road north of Ann Arbor, 6536.
- CARDUUS CRISPIS L. — Plentiful on sterile soil, Shanghai Pit, 3 miles northwest of Ypsilanti, 6923, 6973.

UNIVERSITY OF MICHIGAN

A POLLEN ANALYSIS OF A BOG IN NORTHERN ONTARIO

ELSIE JANSON AND ELIZABETH HALFERT

THIS article deals with the pollen analysis of a peat bog so far north as to be beyond the present range of oak. Nevertheless, oak pollen is so abundant at the lower levels as to indicate a warmer climate during part of postglacial time than that which now prevails.

The bog is in northern Ontario at about 46°-47° N. and 79°-80° W., approximately thirty-four miles northwest of North Bay on the Ferguson Highway. From a fire tower near the Marten River Tourist Camp it can be seen lying in a slight depression, with a ridge rising toward its west end. It is about a half mile long and is conspicuous because of the dark foliage of the black spruce.

The spruces were found by an increment borer to fall into two age classes: one ranging from 52 to 72 years; the other, from 117 to 168 years.

The plants of the bog are listed in order to indicate the subboreal aspect of the present vegetation. The nomenclature is that of *Gray's New Manual of Botany*.

The conifers are *Picea mariana*, *Larix laricina* (mostly young), *Pinus Strobus* (mostly young), *Abies balsamea* (just outside the bog), *Thuja occidentalis* (at the edge), and *Taxus canadensis*. Other trees or large shrubs are *Betula alba* (just outside the bog), *Betula lutea*, *Alnus incana*, and *Populus tremuloides*.

The chief shrubs are *Andromeda glaucophylla*, *Chamaedaphne calyculata*, *Kalmia angustifolia*, *Kalmia polifolia*, *Ledum groenlandicum* (largely confined to the margin), *Vaccinium canadense*, *Vaccinium pennsylvanicum*, *Vaccinium Oxycoccus* (perhaps *V. macrocarpon*), *Nemopanthis mucronata*, and *Rubus idaeus*.

The herbaceous species are *Cornus canadensis*, *Trientalis americana*, *Sarracenia purpurea*, *Smilacina trifolia*, *Spiranthes* sp., *Eriophorum callitrix*, *Carex trisperma*, *Carex oligosperma*, *Carex paupercula*, and *Asplenium Filix-femina*.

Plants were listed from twenty-five areas of twenty-five square meters selected at random in the more open parts of the bog. The percentages of the quadrats in which the principal species occurred are as follows:¹ *Sphagnum*, 96; *Vaccinium Oxycoccus*, 92; *Chamaedaphne calyculata*, 88; *Carex trisperma*, 60; *Kalmia polifolia*, 52; *Carex oligosperma*, 48; *Ledum groenlandicum*, 28; *Andromeda glaucophylla*, 20; *Sarracenia purpurea*, 16; *Vaccinium pennsylvanicum*, 8; *Larix laricina*, 8; *Kalmia angustifolia*, 4; *Picea nigra*, 4; seedlings of *Betula papyrifera*, 4; *Vaccinium canadense*, 4.

The samples of peat were collected with the Davis peat sampler at successive intervals of one foot, beginning at a depth of two feet and continuing until gray glacial clay was reached at the eighteen-foot level. A second set of samples was gathered a few feet away to serve as a check.

The material for examination was taken from the center of each core. The pollen was prepared as suggested by Sears (3), mounted in glycerin jelly, and stained with methyl green. One hundred and

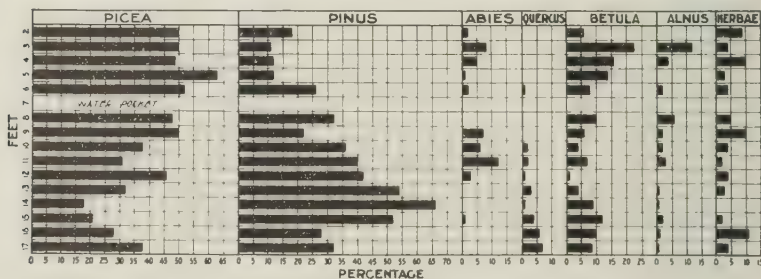


FIG. 3. Pollen profile for a bog in northern Ontario

fifty grains were counted for each layer, this count including only the flowering plants. The absence of data for the seven-foot level is explained by a water pocket at that depth.

In the pollen profile (Fig. 3) it will be noted that *Picea* pollen decreases in amount above the seventeen-foot level until it reaches its minimum at fourteen feet, coincident with the highest peak for *Pinus*. The frequency of *Picea* rises sharply to a minor peak at twelve feet, but reaches its maximum at five feet, above which level it remains uniform.

¹ For these statistics the authors are indebted to Dr. L. A. Kenoyer and Jean McClave.

Pinus pollen is found in increasing amounts from the seventeen-foot to the fourteen-foot level, above which it decreases.

Abies, with the exception of two grains at the fifteen-foot level, does not appear until the twelve-foot depth, but reaches one peak at eleven and another at three feet.

Quercus pollen was found in greatest abundance at the seventeen-foot level (the bottom of the bog) and in decreasing amounts up to the ten-foot level, above which it disappeared. (The identity of one grain at the five-foot level was questioned.)

According to Macoun (2), *Quercus rubra* reaches its northern limit of distribution at 47°50' N., but no oak was observed in the territory that surrounds the bog. Certainly no appreciable amount of oak pollen is nowadays contributed to the peat, or has been for the period during which five feet of peat has been deposited. The results would indicate that the bog was formed during a period of greater warmth than now exists in this region. In a recent survey of pollen profiles for North America, in which data from this paper were used, Sears (4) calls attention to similar conditions in bogs farther to the south. These were the Welland Bog, near Welland, Ontario, analyzed by Auer (1), and a northern and a central Minnesota bog, analyzed by Voss (6). According to a theory of division of post-glacial time into three periods, of increasing warmth, of maximum warmth, and of decreasing warmth (Von Post, 5), this northern Ontario bog was started during the period of maximum warmth, and preserves record of the transition to the period of decreasing warmth.

The decrease of pine and the increase of fir and spruce might suggest an increase of humidity accompanying a decrease in temperature.

SUMMARY

1. This study is concerned with a northern Ontario bog at about 46°-47° N. and 79°-80° W.
2. The plant list indicates the typical subboreal flora of the Canadian coniferous forest.
3. The presence of *Quercus* in the lower layers of the peat and its subsequent absence would indicate inception of the bog deposits during a warmer climate than now prevails in this area.
4. The decrease of *Pinus* and the increase of *Abies* and *Picea* may perhaps signify an increase in humidity.

The authors wish to express appreciation for generous assistance given during their study by Professors H. H. Bartlett, Paul B. Sears, and Leslie A. Kenoyer.

DETROIT, MICHIGAN

LITERATURE CITED

1. AUER, VAINO. 1930. Peat Bogs in Southeastern Canada. Canadian Geol. Surv., Memoirs, No. 162.
2. MACOUN, J. 1883-84. Catalogue of Canadian Plants. Geol. Nat. Hist. Surv. Canada.
3. SEARS, PAUL B. 1930. Common Fossil Pollen of the Erie Basin. Bot. Gaz., 89: 95-106.
4. ——— 1935. Types of North American Pollen Profiles. Ecology, 16: 488-499.
5. VON POST, L. 1930. Problems and Working-Lines in the Postarctic Forest History of Europe. Proc. Fifth Internat. Bot. Congr. (Cambridge), pp. 48-54.
6. VOSS, JOHN. 1934. Postglacial Migration of Forests in Illinois, Wisconsin, and Minnesota. Bot. Gaz., 96: 3-43.

NEW MARINE ALGAE FROM WASHINGTON

CHIN-CHIH JAO

FROM July 26 to the end of December, 1935, the writer worked on marine algae in the Oceanographic Laboratories of the University of Washington, at both Friday Harbor and Seattle, and obtained the cordial assistance of the staffs of these Laboratories in collecting specimens from many different stations. It was very gratifying to be able to get a large number of interesting known species and several new forms. This initial report deals with new species, forms, and records of the west coast of North America. Myxophyceae will be reported in another paper.

The writer wishes to express his gratitude to Dr. Thomas G. Thompson, director of the Oceanographic Laboratories of the University of Washington, to Professor George B. Rigg, and to Dr. Lyman D. Phifer for their assistance in the execution of the work, and to Captain C. T. Larsen of the *Catalyst* (the oceanographic steamer of the University of Washington) and other staff members for help in collecting specimens.

Codiolum pusillum f. **subsessile**, f. nov.¹

(Tab. XII, Fig. 6)

Cellulis usque ad 330 μ longis; clava obovoidea vel ovata, recta, vel curvata, (22-)30-65 μ diam., 95-160 μ longa, membrana crassiuscula; stipite longitudine variante, 19-90 rarissime ad 170 μ longa, plerumque subsessili, parte superiore diametro clavae simili, et parte inferiore paululum attenuata, basali parte paulo tumida et leviter lobata, 19-35 μ diam., hyalina, plus minusve distincte lamellosa.

Cells up to 330 μ long; clava obovoid or ovate, straight, or curved

¹ The type or cotype specimens of the new species and forms which are described in this paper were distributed by the writer to the herbaria of the University of Michigan, Ann Arbor, Michigan, and of the Oceanographic Laboratories of the University of Washington, Friday Harbor, Washington.

(22-) 30-65 μ in diameter, 95-160 μ long, with relatively thick wall; stipes varying in length, 19-90 very rarely up to 170 μ long, usually nearly sessile, upper part of the same diameter as the clava, lower part slightly tapering and somewhat enlarged and slightly lobed at the base, 19-35 μ in diameter, hyaline, more or less distinctly lamellose.

Growing on rotten wood in the uppermost littoral belt, Brown Island, Washington, Aug. and Sept., 1935. Type Jao No. 1007B.

The fronds of this form are shorter and often nearly sessile, in which respect it differs from the typical species. The writer's specimens were collected at different times at the same station. The subsessile plants were found abundantly in all collections. The long-stiped ones, which sometimes have the stalks up to 170 μ long, appeared very rarely among the short-stiped plants. The subsessile form seems to be a constant character of these plants.

There are two species, *C. gregarium* Braun and *C. Petrocelidis* Kuckuck, already reported from the west coast of North America. The first is characterized by the presence of long stipes and the clava is distinctly constricted at the union with the stipe; the second is an endophytic form.

***Phaeophila polymorpha*, sp. nov.**

(Tab. XII, Figg. 7-10)

Filamentis minutis, in vel partim in cuticula concharum inanum repentibus; irregulariter ramosis, dense intertextis; cellulis eiusdem filamentae variantibus forma et magnitudine, plerumque irregulariter tumidis vel lobatis, 23-85 interdum usque ad 180 μ longis, membrana transversa plerumque crassa et lamellosa, 5-10 μ diam., partibus tumidis usque ad 22 μ diam., lobis usque ad 26 μ longa; seta 1, interdum 2 vel 3, in latere superiore cellularum sedente, hyalina, longissima, undulata vel spirali, basi non bullata, maturitate membrana basali transversa crassa et distincte lamellosa e cellula proxima valde separata; chromatophoris singulis, cellulam totam non replentibus; pyrenocidis nonnullis; zoosporis multis, in cellulis vegetativis ordinariis natis.

Filaments minute, creeping in or partly on the superficial layer of empty shells, irregularly branched, densely interwoven; cells varying in form and size in the same filament, usually irregularly tumid or lobed, 23-85 sometimes up to 180 μ long, the cross wall generally thick and lamellose and with a diameter of 5-10 μ , swollen

parts of cells up to $22\ \mu$ in diameter, lobes of the cells up to $26\ \mu$ long: hairs simple, sometimes 2 or 3 together borne on the upper side of the cells, colorless, very long, undulate to spiral, the basal part not swollen, at maturity distinctly separated from the cell below by a very thick and markedly lamellose wall: chromatophore single, not occupying the whole cell, containing several pyrenoids; zoöspores numerous, formed in the ordinary vegetative cells.

Very abundant on several empty shells in Argyle Lagoon, San Juan Island, Washington, Sept. 8, 1935. Type Jao No. 1223.

Until careful examination of the developmental stages of the hairs has been carried through, it is assumed that the hairs of the present plants are directly prolonged from the wall of the ordinary vegetative cells and are not produced from special piliferous cells, as are those found in the genus *Bulbocoleon*. In the earliest stages the hairs are seen as short prolongations which spread out from the outer layer of the thickened cell wall of the vegetative cell and are without cell contents (Pl. XII, Figs. 7-8). As the young hairs grow longer and longer, the inner layer of the cell wall, where the hair originates, becomes very thick and distinctly lamellose. Sometimes this thickened wall may again be separated, with the result that the basal wall of the hair has two or three layers.

The genus *Phaeophila*, as formerly understood, included only the species having an endophytic or partly epiphytic habit; it is found mostly in warm waters rather than in cool waters. No species of this genus has hitherto been reported from the west coast of North America. The endozoic plants described above agree very well with those of the genus *Phaeophila* and are closely related to *P. floridearum* Hauck, but they are characterized by the vegetative cells being quite irregularly lobed or swollen and by an endozoic or a partly ectozoic habit which differs from those of known species.

***Chaetomorpha tenuissima*, sp. nov.**

(Tab. XII, Figg. 3-5)

Frondibus caespitosis; filamentis disco tenui affixis, erectis, regulariter recurvatis, usque ad 2 cm. longis, superne diametro uniformiter cylindricis, inferne paululum et gradatim attenuatis, ad nodos interdum aut leviter tumidis aut constrictis; cellulis 6-10 interdum ad $12\ \mu$ diam., $14-35\ \mu$ longis, membrana crassiuscula et plus minusve distincte lamellosa; cellula terminali mucronata;

cellula basali 5-7 (-10) μ diam., 18-30 μ longa, membrana inferiori crassissima et distincte lamellosa, retinaculis leviter et irregulariter lobatis; cellulis fertilibus in parte superiore filamentae ortis; zoosporis per tubulum brevissimum ad mediam partem cellulae exeuntibus.

Plants tufted; filaments attached by a small disk, cylindrical, erect, regularly curved, with a length up to 2 cm., upper part with the same diameter throughout, lower part slightly and gradually attenuated toward the base, nodes sometimes either tumid or constricted; cells 6-10 up to 12 μ in diameter, 14-35 μ long, wall relatively thick and more or less distinctly lamellous; terminal cell mucronate; basal cell 5-7 (-10) μ diam., 18-30 μ long, with thick and distinctly lamellous wall below, holdfast slightly and irregularly lobed; fertile cells in upper part of the filament; zoöspores escaping by an opening near the middle of the cell, through a very short tube.

Epiphytic on *Acrochaetium rhizoideum* (Drew), comb. nov. (*Rhodochorton rhizoideum* Drew [1928:182]), *Platythamnion pectinatum* Kylin, and *Codium fragile* (Suring.) Hariot, Bell Island; on *Amphiroa tuberculosa* f. *typica* Setch. & Gardn., Turn Island. All specimens were collected from the lower littoral and upper sublittoral belts, Oct. and Sept., 1935. Type Jao No. 1275.

The smallest known species of this genus is *Chaetomorpha minima* Collins & Hervey, a Bermudan plant. According to Collins and Hervey's description and illustrations (1917), it has the filaments 10-20 μ in diameter, not more than 5 (-6?) cells long, ending in an obtuse terminal cell and attaching by a "hemispherical basal cell" in mature filaments, as shown in their drawings. On comparison with the present plants those from Bermuda are seen to be quite different.

***Monostroma fractum*, sp. nov.**

(Tab. XIII, Figg. 8-10)

Thallo membranaceo, molli, et delicato, sessili (?), mox libero, elongato, usque ad 55 cm. longo et 7 cm. lato, margine subplano vel undulato, luteo-viridi, superficie leviter irregulariterque bullata, partibus variis thalli toti in segmenta linearia longitudinaliter diffissis; parte monostromatica 21-24 μ alta; cellulis oblongis, acute angulatis, dense dispositis, plus minusve distincte in longitudinalibus

seriebus, 5–10 μ diam., 10–28 μ longis, in sectione transversa verticaliter obovoideis vel subrectangulatis, 12–14 μ altis, cellulam chromatophora omnino replente.

Thallus membranaceous, soft, and delicate, sessile (?), soon becoming free, elongate, with a length up to 55 cm. and a width up to 7 cm., with nearly plane or undulate margins, yellowish green, surface slightly and irregularly bullate, the whole thallus longitudinally split in various parts into linear segments; monostromous parts 21–24 μ thick; cells oblong, acutely angular, closely set, in more or less distinctly longitudinal series, 5–10 mostly 7 μ in diameter, 10–28 usually 14–17 μ long, in cross section vertically obovoid or subrectangular, 12–14 μ high; chromatophore filling the whole cell.

Mixed with *Ulva Lactuca* floating near the shore, southwest side of Turn Island, Aug. 13, 1935. Type Jao No. 1095.

This species was observed at Turn Island, but only once. The writer's specimens are all large, for no young plants were seen by him. Probably these plants drifted from a point near or within San Juan County. The habit of splitting occurs over the whole surface of the thallus. The earliest stages of the fragmentation appear as very shallow grooves on both sides of the thallus and directly opposite each other, as shown in Plate XIII, Figure 10. Afterward these grooves become deeper and deeper, and then they longitudinally extend and split. The habit is very characteristic of this species, differentiating it from other known species of this genus. Furthermore, the large size, the elongated cells arranged in longitudinal series, and the measurements also distinguish it.

Enteromorpha torta (Mert.) Reinb.

Along the west coast of North America this species was found only at San Diego, California; it is listed by Gardner (1920). The present plants were collected from two stations: Deiner Point, San Juan Island, Sept. and Dec., 1935, and a salt water pond on Maconnell Island, Oct., 1935. The samples from both localities are exactly the same in all aspects, but are mixed with other algae on mud in the uppermost littoral zone. A full description of the local plants follows: filaments unbranched, consisting of two rows of cells; cells rectangular, 10–16 μ in diameter and length, regularly arranged into longitudinal series and more or less in cross series; chromatophore thin, yellowish green, occupying a large part of the cell. This

species is known as a simple filament of a double row of quadrate cells, but it also occasionally branches, sometimes the main branches consisting of a number of cell rows. The local form always appears unbranched and is regularly two cells wide throughout.

Schizogonium murale f. **uniseriatum**, f. nov.

(Tab. XII, Figg. 1-2)

Filamentis plerumque simplicibus, in quibusdam segmentis rarissime duplicibus vel triplicibus, dissepimentis non constrictis. Cetera planta similis formae speciei typicae.

Filaments delicate, forming a soft, tomentose stratum, bright or deep green, the threads 6-13 sometimes up to 17 μ in diameter when the cell wall is unusually thickened, attached to the substratum at various parts of the filament by rhizoidal branches; mostly uniseriate, very rarely 2 or 3 cells wide in certain segments of the filament; rhizoidal branches arising from a single cell of the filament, mostly 2 together, rarely single, 1-10 cells long, or sometimes non-septate and continuous with the segments from which they arise, sometimes with secondary branches; cells 3.5-12 μ long, often shorter than broad; cell wall thick (1.7-5 μ), distinctly lamellose; chromatophore stellate, axile, and containing a large central pyrenoid.

Growing on rotten wood in the uppermost littoral belt, mixed with *Cladophora trichotoma* (?) and *Rhizoclonium riparium*. Deiner Point, San Juan Island, Washington, Sept. to Dec., 1935. Type Jao No. 1249.

The data of the local plants are based upon field material collected at different times and upon four months' observation of plants in culture. In 1916 G. S. West stated that the thallus of *Prasiola* "is either a simple unbranched filament or it forms a flat expansion one layer of cells in thickness. The simple filament is the *Hormidium*-state and when several of these filaments fuse laterally they give rise to the *Schizogonium*-state. In the wider expansions the cells usually divide in two directions in one plane resulting in the *Prasiola*-state." The writer believes that West's opinion is incorrect; his view is based upon some serial observations on both natural and cultured growth of the present plants. Culture work has also been done by Professors Setchell and Gardner (1920). They, too, found that there was no transformation between *Schizogonium* and *Prasiola* in their cultures. The writer believes that transformation of the "*Hor-*

medium-state," the "*Schizogonium*-state," and the "*Prasiola*-state" into one another is impossible.

The genus *Hormidium* as listed in the *Sylloge Algarum* is characterized by the chromatophores being axile and stellate-laciniate in form; as described by some other phycologists, however, *Hormidium* has the chromatophores laciniate-parietal in form. If the species of *Hormidium* have stellate chromatophores, it seems best to combine them under *Schizogonium*, because these two genera, *Hormidium* and *Schizogonium*, as described by De Toni, are too confused with one another. Therefore, even though the present plants are quite like *Hormidium murale* (Lyngb.) Kützinger, it seems better to regard them as a form of *Schizogonium murale* Kützinger.

***Prasiola linearis*, sp. nov.**

(Tab. XIII, Figg. 5-7)

Frondibus dense caespitosis, linearibus, apice rotundatis, margine crenulatis vel crispis, molliter membranaceis, irregulariter intortissimis, 130-670 raro 1400 μ latis, usque ad 10 cm. longis, 23-27 μ crassis; cellulis oblongis vel quadratis, in sectione transversa 11-15 μ altis, in parte marginis crenulata plus minusve irregulariter angulatis 7-11 μ diam., 3.4-7.0 μ longis, ad basim versus duabus seriebus vel pluribus ordinatis, sursum in seriebus numerosis regularibus parallelis a lineis latis intercellularibus longitudinalibus pari intervallo separatis; lineis intercellularibus transversis angustissimis; chromatophoris, praecipue in cellulis inferioribus frondis, distincte stellatis.

Fronds densely tufted, linear, with round apex and crenulate or crisped margin, soft and membranaceous, quite irregularly twisted, 130-670 rarely up to 1400 μ wide, up to 10 cm. long; cells oblong or square, more or less irregularly angular at the crenulate parts of the margin, 7-11 μ in diameter, 3.4-7.0 μ long, near the base of the frond two to several rows, farther up, in numerous rows and almost of the same breadth throughout; wide longitudinal intercellular lines nearly parallel throughout, transverse intercellular lines very narrow; thickness of the frond 23-27 μ ; cells 11-15 μ high in cross section; chromatophores distinctly stellate, especially in the lower cells of the frond.

Growing on gravel and grasses in the upper littoral belt, Argyle Lagoon, San Juan Island, Dec. 17, 1935. Type Jao No. 1261.

These plants were found very abundantly in tufts just below the high tide mark. They look like some species of *Enteromorpha*. In general appearance this species somewhat resembles *P. fluviatilis*, a species inhabiting cold mountain streams, but the present plants have the fronds narrower and thicker and the cells only widely separated longitudinally by the intercellular lines. Another marine form, *P. calophylla*, also has linear fronds, but it is characterized by the fronds being seldom over 1 cm. long, with a truncate apex and a monosiphonous base, in which it differs from *P. linearis*.

Ostreobium Queckettii Born. & Flah.

Fronds endozoic, slender, irregularly and freely branched, interwoven, $2.5\ \mu$ in diameter; often irregularly swollen and lobed in various parts, especially on the ends of branches, up to $15\text{--}45\ \mu$ in diameter.

This species was usually found in various empty shells in company with *Conchocelis rosea* Batters. It is newly recorded for the west coast of North America.

Canoe Island, San Juan Island, Whidby Island, Port Townsend, Port Angeles, and Port Orchard; dredged at a depth of 5–10 fathoms,

Derbesia pacifica, sp. nov.

(Tab. XII, Figg. 11–13)

Frondibus erectis, e repentibus filamentis orientibus, lucido-viridibus, $26\text{--}49\ \mu$ diam., usque ad 4 mm. longitudine, laxe et invicem ramosis, interdum simplicibus; filamentis repentibus plerumque irregulariter tumidis et lobatis vel ramosis; erectis filamentis apice capitatis vel attenuatis, obtuso, $8\text{--}11\ \mu$ diam.; zoosporangiis obovoideis vel interdum subglobosis, $57\text{--}68\ \mu$ diam., $84\text{--}100\ \mu$ longis, zoosporis 16 vel 32; pedicellis $11\text{--}15\ \mu$ diam., $15\text{--}23\ \mu$ longis, membrana plerumque crassa.

Fronds erect, arising from the creeping filaments, bright green, $26\text{--}49\ \mu$ in diameter, with a length up to 4 mm., loosely and alternately branched, sometimes simple, with the partitions near the base of a branch or in the main filaments just above a branch, the main filaments often forming the recurved short branches just above the partition and later the upper part separating off from the partition below; creeping filaments usually irregularly swollen and lobed or branched; apex of the filaments clavate or gradually attenuated,

obtuse, with a diameter of 8–11 μ ; zoösporangia obovoid or sometimes subglobose, 57–68 μ in diameter, 84–100 μ long, containing 16 to 32 zoöspores; pedicel 11–15 μ in diameter, 15–23 μ long, generally with a thickened wall.

Epiphytic on *Amphiroa tuberculosa* f. *typica* in the upper sublittoral belt, Turn Island, Washington, Sept., 1935. Type Jao No. 1273B.

This species was found in a very good fruiting condition at the northeast side of Turn Island. In general appearance it seems like *Derbesia vaucheriaeformis* (Harv.) J. Ag., but differs from it in having shorter zoösporangia and smaller pedicels.

Most of the earlier descriptions of the species of *Derbesia* are incomplete. As described by later authors (Saunders, 1899; Collins, 1909), the zoösporangia of *D. vaucheriaeformis* are obovate or pyriform and measure 100–200 μ in length; the pedicels are one half the diameter of the filaments, or from 15 μ to 20 μ in diameter, as judged by Setchell and Gardner (1920) from Saunders' drawings. The zoösporangia of *D. vaucheriaeformis* are, then, twice as long as those of the present plants and are different in form. In 1920 Setchell and Gardner suggested that the *D. vaucheriaeformis* of Saunders should be placed under *D. marina* as understood by J. G. Agardh. In comparison with the measurements of *D. marina* as mentioned by Setchell and Gardner, the present plants are too small to be referred to this species. Furthermore, the writer thinks that the *D. vaucheriaeformis* of Saunders is also a distinct species. He has had in hand another collection of *Derbesia*, which was found by dredging off Lake Hancock, Whidby Island, Washington, Dec., 1935. These plants are quite different in all respects from *D. pacifica* and *D. marina* and are best classified as *D. vaucheriaeformis*. A brief description would be: plants up to 1 cm. long; filament 30–50 μ in diameter, sporangia obovate or pyriform, 65–80 μ in diameter, 133–190 μ long; pedicels 15–18 μ in diameter, 12–30 μ long, numerous zoöspores in a zoösporangium (Pl. XII, Fig. 14). The writer has carefully measured all his material and found that no filaments are over 50 μ in diameter, that no zoösporangia are greater than 80 μ wide, and that no pedicels are wider than 18 μ . Therefore, he doubts that the *D. vaucheriaeformis* of Saunders should be classified under *D. marina*, a suggestion made by Setchell and Gardner.

Vaucheria litoria Bang & C. Ag.

Plants dioecious, up to 15 cm. tall; filaments 61–114 μ in diameter; oögonia elongate and recurved, 164–190 μ in diameter, 300–323 μ long, terminal on the main filaments or branches in the earlier stages and becoming lateral by the continued growth of the filament beneath after the empty supporting cell is formed between the female organ and the coenocyte; zygotes subglobose to ellipsoid-globose, 160–187 μ in diameter, occupying only the upper part on the oögonium and filling it, with a spore wall of three layers and yellowish at maturity, usually a thin-walled, sterile cell within the oögonium below; antheridia straight, cylindrical, 87–95 μ in diameter, 885–1085 μ long, bearing 2–5 short, conical, and lateral projections, each terminating at maturity in a round pore, through which the antherizoids are finally freed.

Argyle Lagoon, San Juan Island, Sept. 28, 1935. On muddy bottom of the lower littoral belt. This species has been reported only from localities on the east coast of this country, from Massachusetts to New Jersey, and has not hitherto been reported from the west coast. The local plants were found very abundantly and in good fruiting condition. The diagnosis given above seems quite suitable to warrant referring them to *Vaucheria litorea*, except that the filaments are a little wider and the zygotes shorter.

Pylaiella washingtonensis, sp. nov.

(Tab. XIV, Figg. 5–11)

Planta molli, usque ad 20 cm. longitudine, nigro-fusca; filamentis basi paulum et gradatim attenuatis, a parte rhizoidea non ramosa vel raro ramosa affixis, sursum laxe ramosis, ramis inferioribus longissimis et dichotomis, superioribus lateralibus, alternis, non pilos ferentibus, ramis rhizoideis multis, e partibus variis filamenti emergentibus, 1–3 in cellulis singulis, plerumque in filamentum solide intortis; cellulis filamenti primarii 15–19 μ diam., 30–65 μ longis; chromatophoris 3–5, irregulariter liguliformibus; gametangiis elongatis et cylindricis, terminalibus vel intercalaribus, (8–)11–19 μ diam., 34–680 frequenter 110–400 μ longis, plerumque diametro cellulis vegetativis inferioribus similibus; zoosporangiis ignotis.

Plant soft, length up to 20 cm., dark brown; filaments at base slightly and gradually attenuated, attached by a single, very rarely

branched, rhizoid basal portion; loosely branched, lower branches very long and dichotomous, upper branches short, lateral, and alternate, without hairs, rhizoidal branches numerous, arising from various parts of the filament, 1-3 on a single cell, mostly closely twisted on the filament; cells of the primary filaments 15-19 μ in diameter, 30-65 μ long; chromatophores 3-5 in each cell, irregularly band-shaped; gametangia elongate and cylindrical, terminal, or intercalary, (8-)11-19 μ in diameter, 34-680 usually 110-400 μ long, mostly of same diameter as the vegetative cells below; zoö-sporangia unknown.

Very abundant on the concrete wall of Lake Washington Ship Canal, Seattle, Washington, at high water mark, Nov. 10, 1935. Type Jao No. 1235.

These plants are characterized by the large size, closely twisted rhizoidal branchlets, and loosely dichotomous ramification in the lower part of the main filament, in which respects they differ from other species.

The developmental stages of the twisted rhizoidal branches are quite distinctive, as shown in Plate XIV, Figures 9-10. In the earliest stages two adjoining cells grow unequally from the opposite sides, causing the cross wall to be oblique in position. Then from the angular points the rhizoidal branchlets originate and spread out either upward or downward, depending upon the direction of the unequal growth of their supporting cells.

***Punctaria orbiculata*, sp. nov.**

(Tab. XIII, Figg. 1-4)

Frondibus gregariis, late expansis, forma plus minusve orbiculatis, 4-20 cm. latis et longis, vivis colore fusco-olivaceis, siccatis nigro-olivaceis, ad chartas haud adhaerentibus; superficie irregulariter bullata; margine irregulariter undulato, basi rotundato vel cordato; in sectione transversa cellulis marginalibus magnitudine medullaribus ferme similibus, crassitudine inaequabilibus, ex 2-4 paginis cellularum compositis, 46-76 μ crassis; stipite tenuissimo et distincto, in sectione transversa rotundato, 2-3 mm. longo, e radice tenui, parenchymatacea, nigro-fusca et discoidea oriente; superficie visa cellulis corticalibus 4- vel 6-angulatis, (11-)19-31 μ diam.; ex eadem fronde gametangiis et sporangiis emergentibus, solitariis vel 2-5, raro pluribus, gregatim dispositis, in superficiebus ambabus

frondis promiscue sparsis, externe leviter tumidis, 27-40 μ diam.; sporangiis membrana crassa circumdatis et ferme rotundo-angulatis; setis ignotis.

Frond gregarious, broadly expanded, more or less circular in outline, 4-20 cm. broad and long, of an olive-brown color, becoming olive-green when dry, not adhering at all to paper; surface irregularly bullate, the margin irregularly undulate and ruffled, the base round or cordate; in cross section the surface cells are almost of the same size as the medullary cells, occasionally in certain parts only half the width of the inner ones; the thickness of the thallus is not even throughout, but is composed of 2-4 layers of cells, and ranges between 46 and 76 μ ; stipe very delicate and distinct, round in cross section, 2-3 mm. long, arising from a small, parenchymatous, dark brown, disk-shaped holdfast; cortical cells 4- to 6-angular in surface view, (11-)19-31 μ in diameter; gametangia and sporangia arising on the same frond, solitary or 2-5, rarely more, grouped together and promiscuously scattered on both sides of the frond, slightly bulging on the outer surface, 27-40 μ in diameter; sporangia very numerous, with thickened wall and round angles at maturity; hairs unknown.

The writer has had in hand more than thirty specimens of this species, all of which show quite constantly the characteristics described above, especially the circular form of the frond, the distinct stipe, 2-4 layers of cells, and the almost entirely immersed gametangia and sporangia. Probably this new species is related to *Punctaria occidentalis* Setch. & Gardn. and to *P. chartacea* Setch. & Gardn., but it differs from the first in several respects: the fronds do not taper to a stipe at the base; the thickness never exceeds 76 μ ; the fronds are composed of 2-4 layers of cells; and the gametangia and the sporangia are but very slightly bulging on the outer surface. From the second it differs in having the thallus thinner, the margin not fimbriate, and the surface cells not always smaller than the medullary cells. It differs from both in that the fronds are more or less circular in outline and very abruptly contracted to the point of union with the stipe.

Growing on *Zostera* in the lower littoral zone, False Bay, San Juan Island, Washington, Sept. 11, 1935. Type Jao No. 1149

Conchocelis rosea Batters

(Tab. XIV, Fig. 4)

Frond forming pink patches on empty shells; filaments interwoven, 1.5–7.5 μ in diameter, varying in shape and size, oppositely or alternately branched; the filaments near the surface of the frond generally with inflated cells, which reach 30 μ in diameter and 110 μ in length, each containing a distinctly stellate, rose-colored chromatophore; monospores forming in the inflated cells, globose, 13–15 μ in diameter.

This genus and species are newly recorded from the west coast of North America. In the waters of San Juan County and Puget Sound, Washington, these plants are abundantly and widely distributed at a depth of 5–10 fathoms, especially on sandy, gravel, or rocky bottom. In all the writer's collections they show characteristics quite similar to those of Batters' original description and drawings, but the measurements sometimes are a little different among specimens endozoic in different species of host. These variations have been mentioned by Rosenvinge in detail (1931), but the main characters are all the same.

The inner part of the frond is found to be of long, thin, irregularly swollen, and mostly oppositely branched filaments, usually 3–6 μ thick at the cross walls, sometimes only 2 μ thick or even less. On the outermost parts are found more or less scattered, thick, usually curved filaments. The cells of these are always nearly of the same length as the diameter (11–25 μ), mostly tumid, and thick-walled, and generally containing chromatophores deeper in color than the inner filaments. From the inflated cells the monospores are produced. The mature monospores are rarely found in the writer's collections.

Endozoic in various empty shells; dredged at a depth of 5–10 fathoms off Canoe Island, Griffen Bay of San Juan Island, Long Island, Port Townsend, Crescent Bay near Port Angeles, Whidby Island, Port Orchard, and West Point of Seattle, Washington, July to Dec., 1935.

Acrochaetium vagum (Drew), comb. nov.

The local plants have the cells cylindrical or swollen in the middle up to 12 μ in diameter and elongated up to 30 μ . Erect filaments were not found in the vegetative stages, but were abundant in the

fruiting stages as the stalks of the monosporangia, and were 1 or 2, rarely more, cells long and unbranched. The monosporangia were regularly terminal, 1 or 2 on the terminal cell, and obovoid in form. Otherwise the specimens were like the type.

Endophytic in *Pterosiphonia bipinnata* in the lower littoral belt, south of False Bay, San Juan Island, Washington, Sept. 20, 1935.

The type of this species, which was found on the Washington coast at Cape Flattery, was named *Rhodochorton vagum* by Drew in 1928.

Acrochaetium Erythrophyllum, sp. nov.

(Tab. XIV, Figg. 1-3)

Frondibus omnino endophyticis, in hospitem alte penetrantibus, plerumque intercellularibus, raro intracellularibus; filamentis irregulariter ramosis, intertextis; ramis e filamentis principalibus orthogonis emersis; cellulis forma ac magnitudine variantibus, plerumque curvatis et leviter inflatis, $1.5-3.5\ \mu$ diam., $7-52\ \mu$ longis; chromatophoris parietalibus, cellulam complentibus; monosporangiis terminalibus, in hospite circa $\frac{2}{3}$ immersis, obovoideis vel ovatis, $3.4\ \mu$ diam., $6.8\ \mu$ longis.

Fronds wholly endophytic, deeply penetrating into the host plant, mostly intercellular, rarely intracellular; filaments irregularly branched, interwoven; branches mostly given off from the main filaments at right angles; cells varying in shape and size, usually curved and a little swollen, $1.5-3.5\ \mu$ in diameter, $7-15$ sometimes up to $52\ \mu$ long; chromatophores parietal, filling the cell; monosporangia terminal, about two thirds immersed in the host, obovoid or oval, $3.4\ \mu$ in diameter, $6.8\ \mu$ long.

Endophytic in *Erythrophyllum delesserioides*, dredged from a depth of 5-8 fathoms near Port Angeles, Washington, Nov. 10, 1935. Type Jao No. 1238.

In size these plants are almost like *Acrochaetium emergens* (Rosenv.) Hamel, but *A. emergens* has its fronds horizontally extended in the mucilage layer of the host. In general appearance this species also resembles *Rhodochorton coccineum* Drew, but differs from it in having monospores.

Membranoptera Weeksiae Setch. & Gardn.

In general appearance this species is similar to *M. tenuis* Kylin, which was found by dredging off Canoe Island and Peavine Pass,

Washington, but the resemblance is merely in ramification and small size. *M. Weeksiae* differs much from *M. tenuis* in having a distinct macroscopic midrib and microscopic side veins.

The local form is mostly found epizoic on *Sertularia* and epiphytic on *Opuntiella californica* (Farlow) Kylin, or sometimes on gravel or empty shells. Both male and female plants are usually smaller than tetrasporic plants. The cystocarps are almost always on the midrib of the first fork at the apex of the frond. The largest plants found by the writer were only 3 cm. high. The width is mostly 0.5–1.0 sometimes only 0.2 mm. Otherwise they are similar to the typical plants found at Pacific Grove. This species is new to records of the northwest coast of North America.

Port Crescent Bay, near Port Angeles and West Point, Seattle; dredged at a depth of 15–30 m., Nov. 10 and Dec. 7, 1935.

UNIVERSITY OF WASHINGTON

LITERATURE CITED

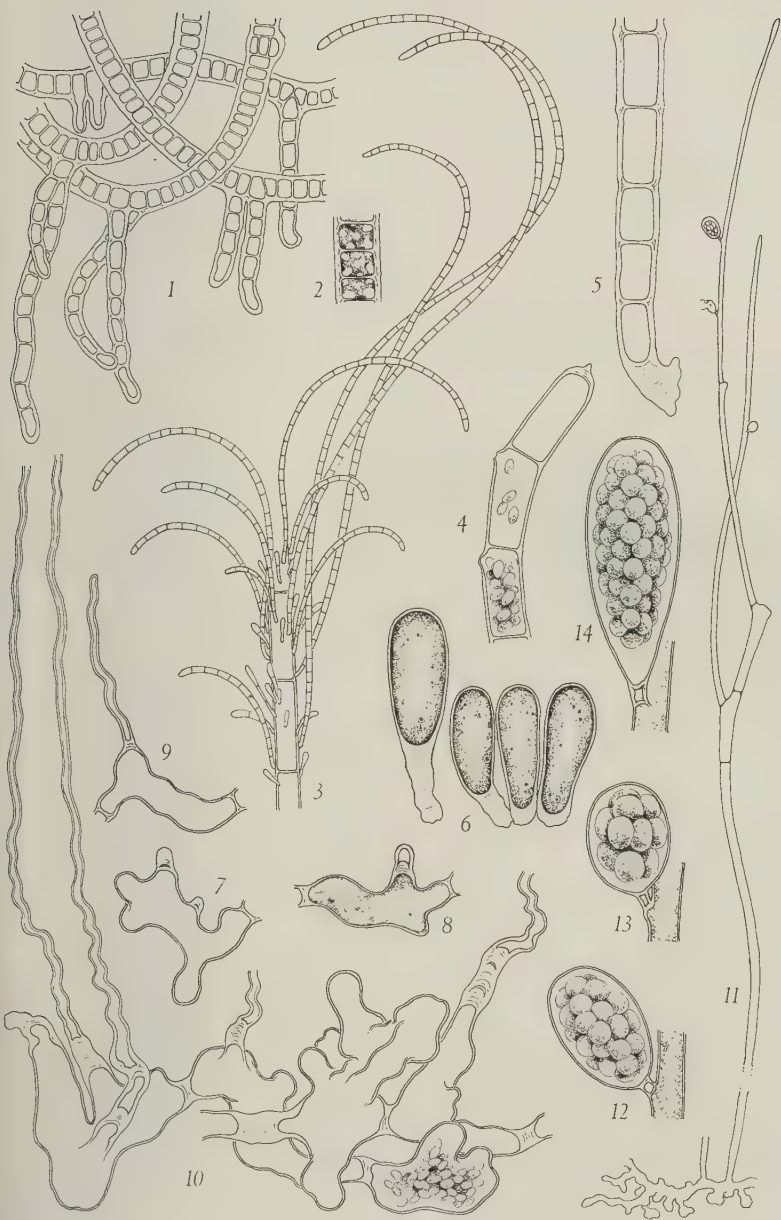
- BATTERS, E. A. L. 1892. On *Conchocelis*, a New Genus of Perforating Algae. *Phyc. Mem.*, 1: 25.
- BRAND, F. 1914. Über die Beziehung der Algengattung *Schizogonium* Kütz. zu *Prasiola* Ag. *Hedwigia*, 54: 295-310.
- COLLINS, F. S. 1907. Some New Green Algae. *Rhodora*, 9: 197-202.
- 1909-18. The Green Algae of North America. Tufts College Studies, Scientific Series, 2: 79-480. 1909. Supplementary Paper, *ibid.*, 3: 69-109. 1912. Second Supplementary Paper, *ibid.*, 4: 1-106. 1918.
- AND HERVEY, A. B. 1917. The Algae of Bermuda. *Proc. Am. Acad. Arts and Sci.*, 53: 1.
- DREW, K. M. 1928. A Revision of the Genera *Chantransia*, *Rhodochorton*, and *Acrochaetium*, with Descriptions of the Marine Species of *Rhodochorton* (Näg.) gen. emend., on the Pacific Coast of North America. *Univ. Calif. Publ. Bot.*, 14: 139-200.
- GARDNER, N. L. 1926. New Rhodophyceae from the Pacific Coast of North America. I. *Univ. Calif. Publ. Bot.*, 13: 205-213.
- HARVEY, W. H. 1858. *Nereis Boreali-Americana*. Part III. *Chlorospermeae* and Supplement. New York.
- HOPPAUGH, K. 1930. A Taxonomic Study of Species of the Genus *Vaucheria* Collected in California. *Am. Journ. Bot.*, 17: 329-347.
- HUBER, J. 1892. Observation sur la valeur morphologique et histologique des poils et des soies dans les Chaetophorées. *Journ. de bot.*, 6: 321-341.
- 1892. Contributions à la connaissance des Chaetophorées, épiphytes et endophytes et de leurs affinités, *Ann. sci. nat., Sér. 7, Bot.*, 16: 265-359.
- JAO, CHIN-CHIH. 1936. New Rhodophyceae from Woods Hole. *Bull. Torr. Bot. Club*, 63: 237-258.
- KJELLMAN, F. R. 1883. The Algae of the Arctic Sea. *Kongl. Svensk. Vet.-Akad. Handl.*, 20(5): 1-350.
- KYLIN, H. 1924. Studien über die Delesseriaceen. *Lund Univ. Årsskr. N. F., Avd. 2*, 20(6): 1-111.
- 1925. The Marine Algae in the Vicinity of the Marine Biological Station at Friday Harbor, Wash. *Ibid.*, Avd. 2, 21(9): 1-87.
- ROSENVINGE, L. K. 1909-31. The Marine Algae of Denmark. *Kongl.-Danske Vidensk. Selsk. Skr. VII, Naturvid. og Math., Afd.*, 7: 1-487.
- SAUNDERS, De A. 1899. Four Siphonaceous Algae of the Pacific Coast. *Bull. Torr. Bot. Club*, 26: 1-4.
- SETCHELL, W. A., AND GARDNER, N. L. 1903. Algae of Northwestern America. *Univ. Calif. Publ. Bot.*, 7: 165-418.
- 1920. The Marine Algae of the Pacific Coast of North America. Part II. *Chlorophyceae*. *Univ. Calif. Publ. Bot.*, 8: 139-374.

- 1924. Phycological Contributions VII. Univ. Calif. Publ. Bot., 13: 1-13.
- 1925. The Marine Algae of the Pacific Coast of North America. Part III. Melanophyceae. Univ. Calif. Publ. Bot., 8: 383-398.
- TONI, J. B. DE. 1889. Sylloge algarum omnium hucusque cognitarum. Vol. I, Sec. I-II, Chlorophyceae.
- 1895. *Ibid.* Vol. III, Fucoideae.
- WEST, G. S. 1916. Algae I. Univ. Press, Cambridge.

EXPLANATION OF PLATE XII

- FIGS. 1-2. *Schizogonium murale* f. *uniseriatum*, f. nov. Figure 1, a group of the filaments, showing the different types of rhizoidal branches, $\times 366$; Figure 2, a part of the filament, showing the chloroplasts, $\times 550$
- FIGS. 3-5. *Chaetomorpha tenuissima*, sp. nov. Figure 3, a group of plants epiphytic on *Acrochaetium rhizoideum*, $\times 55$; Figure 4, an apex of the fruiting filament, showing the mature zoöspores and the mucronate terminal cell, $\times 550$; Figure 5, a basal part of the filament, showing the holdfast and the tumid joints of the cells, $\times 550$
- FIG. 6. *Codiolum pusillum* f. *subsessile*, f. nov. $\times 166$. The three plants to the right represent the common form
- FIGS. 7-10. *Phaeophila polymorpha*, sp. nov. $\times 550$. Figures 7-9, young cells, showing the developmental stages of the hair; Figure 10, typical vegetative cells and a mature zoösporangium
- FIGS. 11-13. *Derbesia pacifica*, sp. nov. Figure 11, a part of the plant, showing the creeping and the erect filaments, the upper part of the main filament being broken off, about $\times 30$; Figures 12-13, the mature zoösporangia, $\times 188$
- FIG. 14. *Derbesia vaucheriaeformis* (Harv.) J. Ag. $\times 188$. A mature zoösporangium

PLATE XII



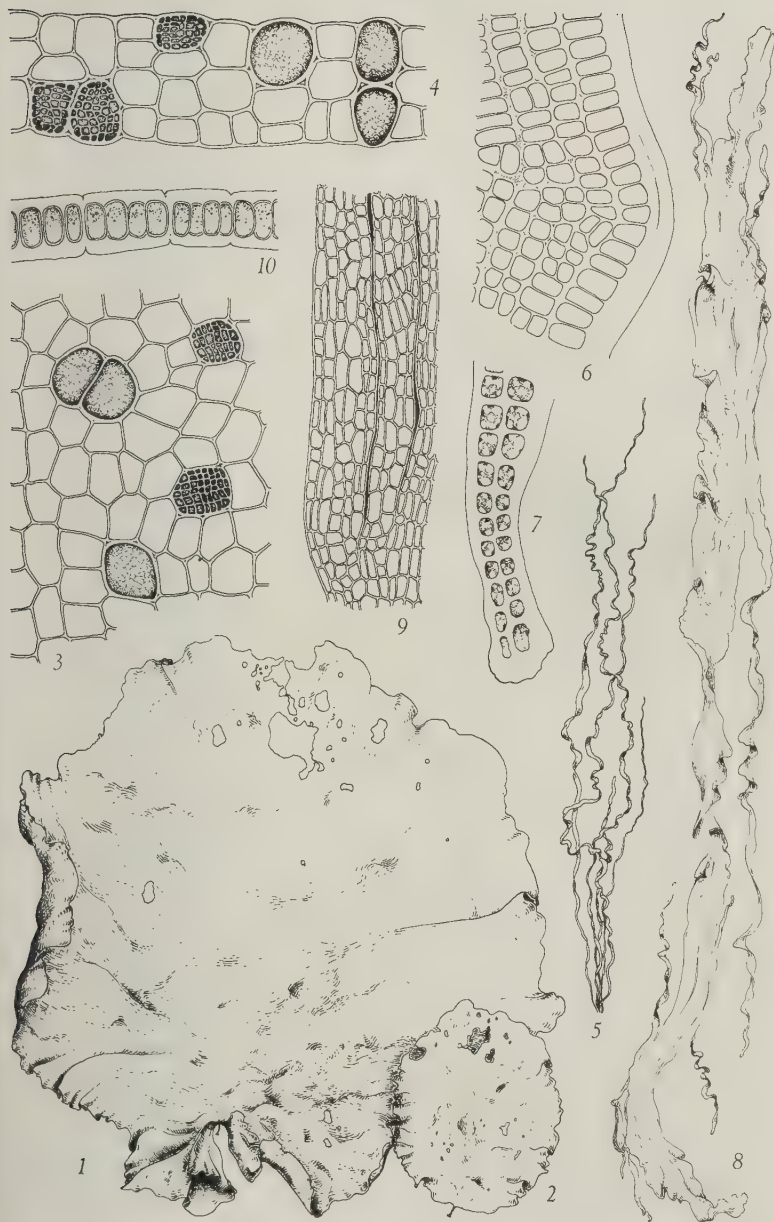
EXPLANATION OF PLATE XIII

FIGS. 1-4. *Punctaria orbiculata*, sp. nov. Figures 1-2, two mature plants of different sizes, sketched from the living plants, $\times 0.5$; Figure 3, a portion of the surface, showing the form and the arrangement of the vegetative cells and the mature sporangia and gametangia, $\times 250$; Figure 4, a cross section of the frond, $\times 250$

FIGS. 5-7. *Prasiola linearis* sp. nov. Figure 5, a habit sketch of a group of living plants, $\times 1$; Figure 6, a marginal portion of the frond, showing the arrangement of the cells, $\times 550$; Figure 7, a basal part of the frond, containing two rows of cells and showing the stellate chromatophores, $\times 550$

FIGS. 8-10. *Monostroma fractum*, sp. nov. Figure 8, a habit sketch of a living plant, $\times 0.5$; Figure 9, a portion of the frond, showing the form and the arrangement of the cells and the fragmentation grooves, $\times 250$; Figure 10, a cross section of the frond, showing the cell form and the fragmentation grooves, $\times 360$

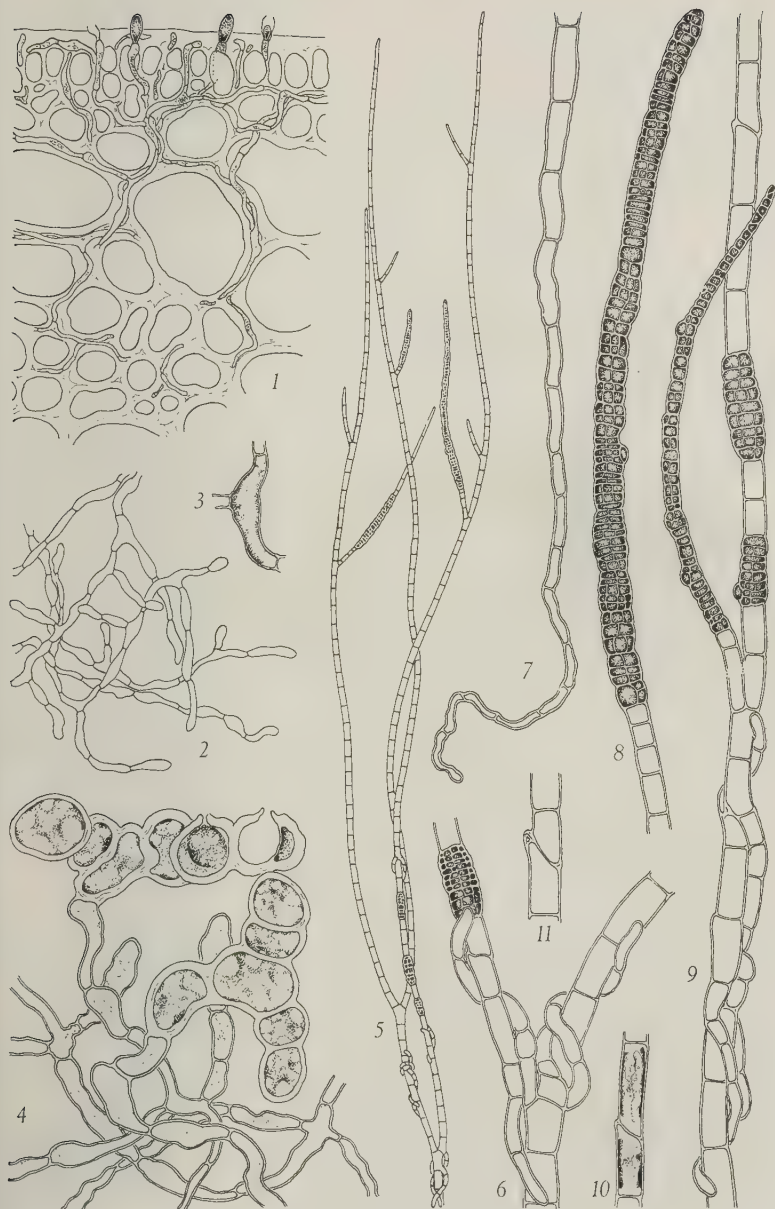
PLATE XIII



EXPLANATION OF PLATE XIV

- FIGS. 1-3. *Acrochaetium Erythrophyllum*, sp. nov. Figure 1, a transverse section of the frond of *Erythrophyllum delesserioides*, showing the endophytic filaments of *Acrochaetium Erythrophyllum*, with subendophytic monosporangia, $\times 550$; Figure 2, the endophytic filaments viewed from the surface of the host, $\times 550$; Figure 3, a single cell, showing the chromatophore, $\times 1100$.
- FIG. 4. *Conchocelis rosea* Batters. $\times 550$. A group of plants, showing the vegetative filaments and the fertile cell rows, with the monosporangia.
- FIGS. 5-11. *Pylaiella washingtoniensis*, sp. nov. Figure 5, a part of the filament, showing the ramification and the terminal and the intercalary gametangia, about $\times 52$; Figures 6, 9, parts of the filaments, showing the rhizoidal branches and two types of gametangia, $\times 250$; Figure 7, a holdfast, $\times 250$; Figure 8, a terminal gametangium, $\times 250$; Figures 10-11, parts of the filament, showing the earlier developmental stages of the rhizoidal branches and the chromatophores, $\times 250$.

PLATE XIV



NOTES ON NEW OR UNUSUAL MICHIGAN DISCOMYCETES. IV *

BESSIE B. KANOUSE

NINETEEN species that are additions to the record of Michigan discomycetes are listed. One new species, *Aleuria michiganensis*, sp. nov., is described and one new combination, *Peziza maturescens* (Boud.) Kanouse, is made. All collections cited have been determined by the author and are deposited in the Herbarium of the University of Michigan.

This is a continuation of previous studies made by the author (2-4).

LIST OF SPECIES

Aleuria michiganensis, sp. nov.¹ — Apothecia solitary or scattered, short-stipitate, convex, reaching a diameter of 2-4 cm., surface plane becoming rugose; hypothecium thick, soft-spongy and watery, parenchymatous, cells very large and thin-walled, "pecan-brown" (R.)² to "vinaceous tawny" or "pinkish buff," context "light vinaceous fawn," margin uneven, sterile, composed of long, blunt, thin-walled cells, stipe 1 cm. thick, 5 mm. high; asci cylindric-clavate, 8-spored, $325-400 \times 18-25 \mu$; spores elliptical, smooth in age becoming finely irregularly reticulate, without oil drops, granular contents disposed at the ends of the spores, hyaline, becoming faintly yellowish brown, $18-22 \times 10-12$

* Papers from the Department of Botany and the Herbarium of the University of Michigan, No. 536.

¹ ***Aleuria michiganensis***, sp. nov. — Apotheciis solitariis vel sparsis, substipitatis, convexis, 2-4 cm. latis, planis deinde rugosis, margine iniquo, sterili, stipite 1 cm. denso, 5 mm. alto; hypotheciis densis, molliter spongiosis, aquosis, compositis laxe ex magnis cellulis; ascis cylindrico-clavatis, 8-sporis, $325-400 \times 18-25 \mu$; sporidiis ellipticis, primum levibus deinde irregulariter subreticulatis, sine oleariis guttis, primum hyalinis deinde pallide fuscis, $18-22 \times 10-12 \mu$; paraphysibus copiosis, apice incrassatis, $10-12 \mu$ diametro.

In ligno putrido. Legit Alexander H. Smith (3953), Scio, Michigan, June 27, 1935. Specimen typicum in herbario Universitatis Michiganensis conservatum.

² Ridgway, R., *Color Standards and Color Nomenclature*. 1912.

μ ; paraphyses numerous, enlarged at the apices, reaching a diameter of 10–12 μ .

On very rotten wood. Type collected at Scio, Michigan, June 27, 1935, by Alexander H. Smith (3953); on wet wood, Dexter, Michigan, June 11, 1935, A. H. Smith (3952). Type deposited in the Herbarium of the University of Michigan.

This fungus is illustrated by Boudier (1) in his plate No. 278 under the name *Aleuria isabellina* Worth. G. Smith. Boudier's plate and text seem to refer to a fungus very different from the one named and illustrated by Worthington G. Smith (11) as *Aleuria isabellina*. Our collections are like those described by Boudier in all respects except one. In our specimens the mature spores are finely reticulated. He seems to have overlooked this point. That could easily have happened, since the reticulations do not appear on immature spores. The texture of the fresh plants is very characteristic. They are soft and water-soaked, and become badly infected with grubs even in the early stages of development. That the fungus is so quickly and completely destroyed by grubs probably accounts for the fact that it is not often encountered. On drying the size is greatly reduced; the texture becomes horny and the color changes to a dark reddish brown. A thick weft of hyphae closely resembling the vesiculose cells found in the hypothecium is usually found on the substratum underneath the apothecia. Numerous spherical bodies resembling conidia are frequently present. The relationship of these to the fungus has not been determined.

ASCOBOLUS CARBONARIUS Karst. — On burnt-over soil, Lakeland, July 9, 1935, Smith (1492).

CISTELLA MALI (Rehm) Nannf. — On old wood, George Reserve, University of Michigan, Pinckney, May 15, 1935, Kanouse (1561). This species has very small apothecia, which measure less than 0.5 mm. in diameter. It is recognizable in part by the spherical swellings at the tips of the hairs on the outside of the apothecia and by the fact that the hairs are held together more or less definitely in toothlike fascicles. The asci are 4- and 8-spored.

COCCOMYCES CORONATUS (Fr.) de Not. (Pl. XV, Fig. 1). — On decaying leaves, chiefly poplar, Marquette, Sept. 14, 1935, E. B. and E. E. Mains (35–30).

DASYSCYPHA PULVERULENTA (Lib.) Sacc. var. *SOLFATERA* Sacc. —

On decaying needles of *Pinus* sp., Little Lake, Sept. 13, 1934, E. B. and E. E. Mains (34-197). Phillips (8), in commenting upon *Lachnella solfatera* (Cke. & Ellis) Phill., says that this species is nearly related to *L. pulverulenta* Lib., which by some authors would be considered only a variety. He gives the color as citrine yellow. Saccardo properly transferred the species to the genus *Dasyscypha* and made the fungus a variety of *D. pulverulenta*. No. 1730 of Rehm's *Ascomyceten* is a decidedly red-yellow plant, and the citrine-yellow plants in Phillips' English collections and our Michigan specimens seem to fall properly within the limits of a variety.

GEOPYXIS FLAVIDULA Vel. — On wet burnt-over sand, Dexter, June 11, 1935, Smith (1341). The plants in our collections seem to be like those described and illustrated by Velenovsky (14). They are short-stipitate. The apothecia become expanded and are somewhat scalloped when fully expanded. The spores measure $14-16(18) \times 8-9 \mu$.

HELOTIUM MACROSPORUM Pk. — On sticks, Marquette, Sept. 6, 1934, Mains³ (34-47). Our collection was compared with the type in the New York State Museum, Albany, New York. The species is known by its large robust stature and by the unusually large spores, which measure $18-20 \times 8 \mu$.

HELOTIUM SPARSUM Boud. — On rotting leaves in swamp, Marquette, Sept. 10, 1934, Mains (34-144). The apothecia are minute and hyaline. They bear asci and spores that are remarkably large for so small a plant. The width of the cups when spread by the pressure of a cover glass is only about 400μ , whereas the asci measure $100-110 \times 10-12 \mu$ and the spores $18 \times 7-8 \mu$. The peridium is poorly developed. Boudier's (1) plate No. 495 is an excellent illustration.

HELVELLA LATISPORA Boud. (Pl. XVI, Fig. 3). — On ground in oak woods, Scio, June 24, 1935, Smith (3954). The species was found in abundance on high upland hillsides, which is a unique location for helvellas. Boudier's plate No. 233 is a good reproduction. The stipes in our Michigan specimens measured 6-9 cm. in height by 6 mm. in width. The edges of the apothecia were inrolled in a very characteristic manner, as is shown by Boudier and as

³ When no initials are used with this name, the collector is always E. B. Mains.

is also shown in the photograph which accompanies this paper (see Pl. XVI). The color of the tops of the apothecia is "avel-laneous" (R.), and underneath it is "tilleul buff."

HUMARINA AGGREGATA (B. & C.) Seaver. — On burnt-over sandy soil, Ann Arbor, June 11, 1935, Smith (3955). The fungus was found growing in confluent masses. The delicate fringe at the edges of the apothecia is a diagnostic character.

HUMARINA ORTHOTRICHA (Cke. & Ellis) Seaver. — On earth among mosses, Ann Arbor, June 12-17, 1935, Smith (1339).

HUMARINA TETRASPORA (Fuck.) Seaver. — On peat in a bog, Ann Arbor, March 30, 1930, Smith (3957). This species is easily distinguished by the four large spores in each ascus.

LAMPROSPORA DENTONIA Brenckle. — On wet earth, Silver Lake, Dexter, June 10, 1935, Smith (1340).

MELACHROIA XANTHOMELA (Pers.) Boud. (Pl. XV, Fig. 2). — On rotting bark, L'Anse, Sept. 6, 1935, Mains (35-28); on soil among mosses, Marquette, Sept. 14, 1935, Mains (35-29). This is a strikingly beautiful species. It is distinguished by the greenish yellow color of the apothecia, the conspicuous heavy, dark brown margin, and the delicate dark-colored fleckings on the outside of the apothecia. The fungus is apparently rarely collected.

Rehm considered that a subiculum was present in the genus *Melachroia*. This character, however, does not seem to be constant. Starbäck (13) refers to European specimens at Upsala in which the subiculum is lacking. He states that Rehm regarded them as *M. xanthomela* f. *athallina* Rehm. In our collections there is no subiculum, nor is there any in the specimens of *M. xanthomela* f. *americana* Rehm in Rehm's *Ascomyceten* No. 403b, which has been examined by the author.

The color of the fungus changes decidedly in drying. The inside is then reddish brown and the outside is considerably darker. The yellow and green shades entirely disappear.

M. xanthomela f. *americana* was separated because of the somewhat contracted basal portion of the apothecia. Some of our plants and those of Boudier's illustrations of *M. xanthomela* show this character, but it does not seem sufficient evidence upon which to establish a variety. Considering the apparent variability in the color, the presence or the absence of a subiculum, and the

slight differences in the shape of the base, it seems probable that the two forms, f. *athallina* and f. *americana*, are but reasonable variations within the limits of the species.

M. livida Malençon (6) seems distinct from *M. xanthomela* by the larger asci and spores and by its green color. *M. Nymani* Starb. is said to have a pronounced olive-green color and ornamented spores.

PEZIZA CEREAE Sow. (Pl. XVI, Figs. 1-2). — In basement of a house, Warrensburg, New York, Sept. 12, 1934, Smith (785); on sand in a garage, Ann Arbor, June 1, 1925, Jean D. Arnold (351). This species has been misinterpreted and confused with other species in the genus. It is apparently rarely collected. Although the specific characters are clearly marked, the species has been questioned by some authors. Lloyd (5) published a good photograph of a single apothecium. His accompanying comments based upon his observations of this North American collection describe our plants. The waxy, fragile consistency of the cups, together with the almost translucent appearance of the fresh plants, are distinguishing macroscopic features. In the dry condition the apothecia are very brittle. The spores are smooth, hyaline, and measure $11-13 \times 8-9 \mu$. The accompanying photographs (see Pl. XVI) show the substipitate condition, which somewhat suggests a species of *Macropodia*. However, the fungus cannot be assigned to that genus because of the absence of hairs or tomentum and because of the texture. As Lloyd pointed out, the illustrations published by Sowerby (12) do not fully represent the fungus. No. 135 in Ellis' North American Fungi is incorrectly named *Peziza cerea* Sow.

Peziza maturescens (Boud.), comb. nov. — On sticks in woods, Pinckney, July 1, 1935, Smith (3560). This fungus is apparently uncommon, since it is not listed for North America by Seaver (10). Boudier (1) has an excellent plate, which shows the velvety surface of the apothecium and gives a perfect reproduction of the colors of the fresh plants. The species was called *Disciotis maturescens* by Boudier. Saccardo (9) transferred it to the genus *Discina*, but it cannot be included in that genus, since the spores are not apiculate.

SCUTULA EPIGENA (Nyl.) Rehm. — On *Peltigera canina* (L.) Willd., Dexter, June 16, 1935, Smith (1344).

SPHAEROSPORA TRECHISPORA (Fuck.) Seaver. — On rich soil in woods, Scio, July 23, 1935, Smith (3964).

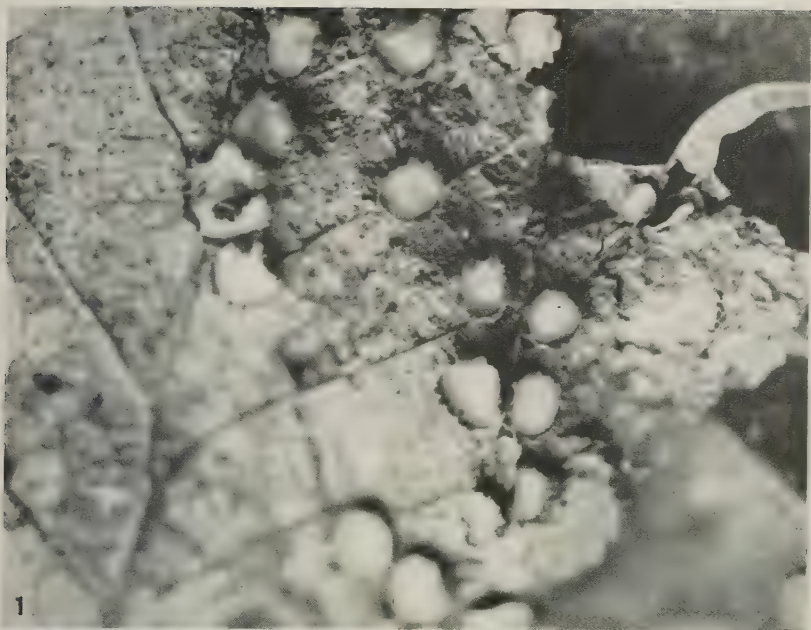
TAPESIA TENEBROSA (Karst.) Nannf. — On oak bark, Cascade Glen, Ann Arbor, May 10, 1933, Smith (33-13). The distinguishing feature about this species is the presence of stroma-like bases of coarse dark hyphae on which the apothecia are seated. Nannfeldt (7) has studied this structure and illustrates it well. The asci in the Michigan specimens measure $35-40 \times 5-6 \mu$; the spores, $5-5.5 \times 1.5-2 \mu$.

UNIVERSITY OF MICHIGAN

LITERATURE CITED

1. BOUDIER, E. 1905-10. *Icones mycologicae ou iconographie des champignons de France*. Paris.
2. KANOUSE, B. B. 1934. Notes on New or Unusual Michigan Discomycetes. I. Pap. Mich. Acad. Sci., Arts and Letters, 19 (1933): 93-106.
3. ——— 1935. Notes on New or Unusual Michigan Discomycetes. II. *Ibid.*, 20 (1934): 65-78.
4. ——— 1936. Notes on New or Unusual Michigan Discomycetes. III. *Ibid.*, 21 (1935): 97-104.
5. LLOYD, C. G. 1916. *Mycological Notes*, No. 44: 606-620.
6. MALENÇON, G. 1927. Quelques espèces inédites du Discomycetes. Bull. Soc. Myc. Fr., 43: 95-106, 1 pl.
7. NANNFELDT, J. A. 1932. Studien über die Morphologie und Systematik der nichlichtenisierten inoperculaten Discomyceten. Nova Acta Regiae Societatis Scientiarum Upsaliensis, Ser. IV. 8, No. 2: 1-368. Upsala.
8. PHILLIPS, W. 1887. *A Manual of the British Discomycetes*. London.
9. SACCARDO, P. A. 1895. *Sylloge Fungorum*, 11: 395. Pavia.
10. SEAVER, F. J. 1928. *The North American Cup-Fungi*. New York.
11. SMITH, W. G. 1892. *New Ascomycetous Fungi*. Grev., 1: 136. 2 pls.
12. SOWERBY, J. 1797. *Colored Figures of English Fungi*. London.
13. STARBÄCK, K. 1895. Discomyceten-Studien. Bih. Till. k. Sv. Vet.-Akad., Handl. 21, Afd. 3, No. 5: 1-42, 1 pl.
14. VELENOVSKY, J. 1934. *Monographia Discomycetum Bohemiae*. Pars I, Pars II. Prague.

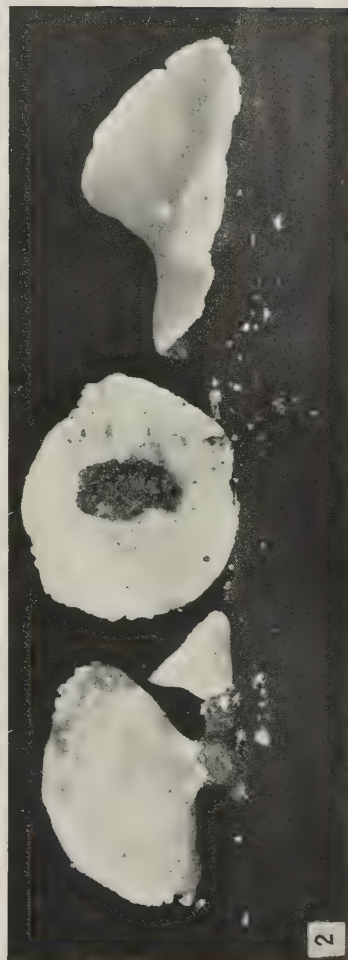
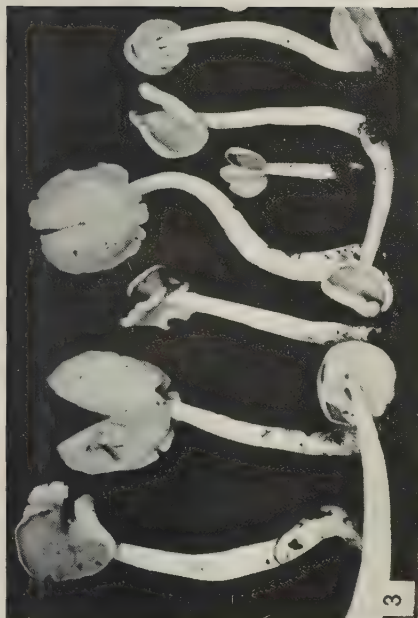
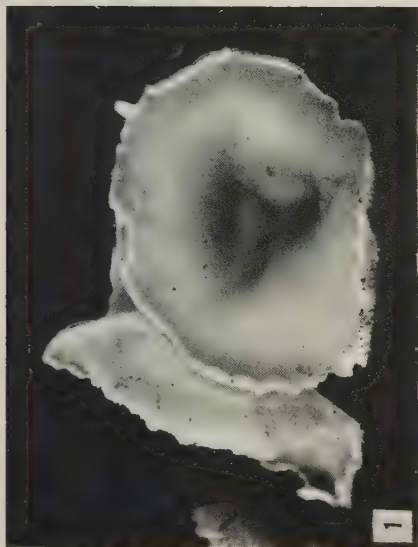
PLATE XV



Photographs by E. B. Mains

FIG. 1. *Coccomyces coronatus* (Fr.) de Not., $\times 5$

FIG. 2. *Melachroia xanthomela* (Pers.) Boud., $\times 9$



FIGS. 1-2. *Peziza cerea* Sow.

FIG. 3. *Hebelia latispora* Boud.

Photographs by A. H. Smith

CELL OUTGROWTHS FROM WOUNDED SURFACES OF PLANTS IN DAMP ATMOSPHERES *

CARL D. LA RUE

INTRODUCTION

THE healing of wounds on leaves and stems of plants has been treated extensively by Massart (30), who studied the reaction of plant surfaces exposed to the open air. Usually, under such conditions, the tissues soon form a protective layer of periderm, as Massart found and as Wylie (53), Priestley and Woffenden (32), and others have since observed. Under more moist atmospheric conditions periderm is not ordinarily formed at once, though it may develop later, and some sort of hypertrophy of the cells on the exposed surfaces takes place. The literature of callus, as the hypertrophied masses are often called, is extensive; since it is reviewed in some detail by Küster (17) it is unnecessary to cite references here other than those which have special bearing on the study reported in this paper.

The well-known experiments of Haberlandt (7) on the outgrowths on cut surfaces of kohlrabi stems seem to have some connection with the structures observed in the present study. He found that surfaces which had been washed thoroughly with water did not proliferate, but that if, after they had been washed, the wounds were covered with crushed parenchyma of kohlrabi, the outgrowths would form as on the unwashed surfaces. Haberlandt thought the proliferations were caused by the presence of a wound hormone which had been removed by washing with water. Wehnelt (47) found that a number of substances would cause cell division in the tissue of the inside of bean pods and that this result could be produced by water and alcoholic extracts of young bean leaves.

* Papers from the Department of Botany of the University of Michigan, No. 561. A part of this work was done at the University of Michigan Biological Station.

Cell outgrowths seem to be related to the lenticular outgrowths described by Devaux (5), Schilling (36), Wisniewski (50), Hahn, Hartley, and Rhoades (9), and numerous others. Likewise, they appear not unrelated to the hypertrophied tissues of numerous galls due to various agencies (Küster, 16; Smith, 39).

The intumescences of plants which have been studied by Dale (4), Atkinson (1), Wallace (45), Sorauer (40), La Rue (21, 22, 23), Von Schrenk (44), Wolf (51), Küster (14, 15), Harvey (10), and other investigators, although they begin their development under the epidermis, are otherwise not unlike the cell hypertrophies which develop on the tissues that have been exposed by wounding.

Tyloses (6, 13) are cell protuberances which appear to belong to the same general group of tissue reactions as callus, intumescences, and galls, and the peculiar pearly droplike growths, known to the Germans as *Perldrüsen* (46), which often appear on leaves of the Virginia creeper and of the Japanese ivy in wet seasons, seem to belong in the same category.

For a number of years the author has been concerned with the abnormal growth and reactions of various plants, as well as with the behavior of such tissues in regeneration (18, 19, 20, 24, 25, 28). He became interested in the idea of totipotent cells as discussed by Erwin F. Smith (39), and the present study began in a survey of plant tissues to determine which possessed totipotency and thus conceivably were able to regenerate. Recent successes in the culture of tissues of spermatophytes by White (49) and La Rue (26, 27) may make the survey more valuable, since it may aid in some degree in the choice of tissues for attempted cultures.

EXPERIMENTAL WORK

Callus development on leaves

Mature leaves of the different species were cut or torn in a variety of ways to expose the mesophyll. Without further treatment the pieces thus produced were laid on moist paper toweling in closed damp chambers. Experience with young leaves had shown that they were unusually subject to decay and seldom lived long enough to show full reaction.

In many leaves the development was not extensive enough to deserve the name "callus," but in others it could properly be so

designated. If true callus developed, it appeared first and was most fully exhibited on the cut ends of veins or along the sides of exposed vascular bundles. Callus often appeared on the cut ends of petioles, and not infrequently on the bases of petioles not wounded beyond the injury incident to their removal from their twigs.

The outgrowths usually appeared as pronounced swellings of the uninjured cells on the exposed surfaces. These were much like the hypertrophies seen in intumescences on leaves. In some species they developed from one part of the mesophyll, in others from another part, and in many they arose indifferently from all parts of the mesophyll, and even from the epidermis.

Between different species of plants there were many differences in the aspect of the protuberances which arose from the cells. In certain species these swellings arose from every unwounded cell on the cut surface, but in others only a cell here and there was involved. Some leaves ceased apparent development when the existing cells had swollen to their limit, but in many there was a multiplication of cells with the resultant formation of callus. Where cell multiplication was abundant a true callus did not always form, for in numerous examples the repeated cell division led to the production of chains of cells which did not fuse to form callus. On



FIG. 4. Cell outgrowths from wounded leaves. The figures were drawn from prepared slides with a camera lucida. A. Cell outgrowths on a wounded leaf of *Vinca minor*. B. Cross section of a leaf of *Aster laevis*, showing a strong callus development from mesophyll exposed by a wound. C. Cross section of a leaf of *Nerium oleander*. The beginning of periderm development may be seen in the outer part of the callus

some of these chains the terminal cells expanded into strange and grotesque shapes similar to those pictured by Vöchting (43), from kohlrabi, or the forms shown by the epidermal outgrowths on leaves attacked by mites (16, 17, 41). Figure 4 gives an idea of the appearance of these outgrowths, although in these sections the ex-

pansion of the cells is less pronounced than it appears to be when the wounded surface is examined with a binocular microscope. Figure 4A is a cross section of a wounded leaf of *Vinca minor*. The callus tissue appears at the right of the figure. Figure 4B is a cross section of a wounded leaf of *Aster laevis*, which shows the very strong development of callus that is characteristic of this species. Figure 4C is a cross section of a sclerophyllous leaf of *Nerium oleander*. At the left end of the section callus appears in which periderm is beginning to form.

The number of leaves which produced no outgrowths is surprisingly large, and indicates that the mature leaf is not usually made up of reactive, much less totipotent, cells.

The reactions of the leaves to wounding are recorded in Table I.

TABLE I

DEVELOPMENT OF CALLUS ON WOUNDED SURFACES OF LEAVES

	1 = callus very well developed		
	2 = callus slightly developed		
	3 = no callus		
	4 = callus on ends of petioles		
	5 = adventitious roots produced		
<i>Species</i>	<i>Extent of outgrowth</i>	<i>Species</i>	<i>Extent of outgrowth</i>
Acacia Riceana	3	Chrysanthemum maximum .	2
Acer pennsylvanicum	3	Citrus aurantium	2
Acer rubrum	3	Clintonia borealis	3
Acer saccharum	3	Coleus Blumei	3, 5
Acorus calamus	3	Comandra umbellata	2
Alnus incana	3	Commelina bengalensis	3
Aloe ciliaris	1	Cotyledon fulgens.....	3, 5
Althaea rosea	2	Crassula arborescens	3, 5
Antirrhinum majus	3	Crataegus sp.	1, 4
Aquilegia canadensis	2	Cupressus Lawsoniana	3
Asclepias syriaca	1	Cynoglossum vulgare	3
Aster laevis	1	Echeveria cristata	3, 5
Aucuba japonica	2	Echeveria glauca	3
Begonia peltata	3, 5	Echeveria leucotrichia	3, 5
Begonia Scharffiana	3, 5	Echeveria scaphylla	3
Brassica nigra	3	Erigeron canadensis	3
Bryophyllum calycinum	2	Euonymus aureus	1
Bryophyllum crenatum	1	Euonymus variegatus	1
Byrnessia Weinbergii	3, 5	Fagus grandifolia	3
Chenopodium album	1	Ficus rubescens	3
Chrysanthemum leucanthemum	1	Fragaria virginica	4
		Fuchsia hybrida	2, 5

<i>Species</i>	<i>Extent of outgrowth</i>	<i>Species</i>	<i>Extent of outgrowth</i>
<i>Gaultheria procumbens</i>	2	<i>Populus tacamahaca</i>	3, 4
<i>Gnaphalium lanatum</i>	3	<i>Populus tremuloides</i>	3, 4
<i>Hedera helix</i>	1, 4, 5	<i>Pteris aquilina</i>	3
<i>Helianthus annuus</i>	3	<i>Pyrola elliptica</i>	3
<i>Hibiscus rosa-sinensis</i>	2	<i>Quercus bicolor</i>	3
<i>Hibiscus tiliaceus</i>	3	<i>Quercus borealis</i>	3
<i>Hoya carnosa</i>	1, 4	<i>Radicula aquatica</i>	1, 5
<i>Humulus lupulus</i>	4	<i>Reinwardtia indica</i>	3
<i>Iris lacustris</i>	3	<i>Rumex acetosella</i>	3
<i>Kalanchoe carnea</i>	3, 5	<i>Salix longifolia</i>	1, 4
<i>Kalanchoe marmorata</i>	3	<i>Sambucus canadensis</i>	3
<i>Lenophyllum guttatum</i>	3, 5	<i>Sansevieria cylindrica</i>	3, 5
<i>Ligustrum japonicum</i>	2	<i>Sansevieria zeylanica</i>	3, 5
<i>Lychnis alba</i>	3	<i>Sarracenia purpurea</i>	3
<i>Lysimachia nummularia</i>	2, 4, 5	<i>Sedum acre</i>	3
<i>Matthiola incana</i>	3	<i>Sedum compressum</i>	3
<i>Melianthus major</i>	3	<i>Sequoia sempervirens</i>	3
<i>Mitchella repens</i>	2	<i>Solanum miniatum</i>	3
<i>Myrtis communis</i>	2	<i>Tilia americana</i>	3
<i>Nelumbo lutea</i>	3	<i>Ulmus americana</i>	3
<i>Nerium oleander</i>	1, 4	<i>Utricularia</i> sp.	3
<i>Nicotiana glauca</i>	3	<i>Vaccinium canadense</i>	3
<i>Nymphaea advena</i>	3	<i>Verbascum thapsus</i>	3
<i>Oenothera biennis</i>	3	<i>Veronica speciosa</i>	3
<i>Pereskia Pereskia</i>	3, 5	<i>Vinca major</i>	1
<i>Polygonum amphibium</i>	3	<i>Vinca minor</i>	1
<i>Polystichum aculeatum</i>	3	<i>Vitis vulpina</i>	3, 4
<i>Populus grandidentata</i>	3, 4	<i>Ximene americana</i>	2

It is difficult to draw conclusions concerning the reactions of these leaves. The ferns, which have each been tried more than once, show no reaction whatever. However, the first and the second and, sometimes, the third leaf of a young fern plant may undergo regeneration and produce gametophytes, as Heilbronn (11), Woronin (52), and Lawton (29) have shown. Holden (12) reported the formation of cell outgrowths in wounds on the petioles of *Pteris aquilina*. Great variation was to be expected in such a miscellaneous group, and it is difficult to draw conclusions concerning the reactions of these leaves.

As a group, the monocotyledonous plants are probably to be regarded as nonreactive, having little power to regenerate or to produce outgrowths. This idea is borne out by the behavior of *Iris*, *Acoris*, *Clintonia*, and *Commelina*, and by the results of Rodger (34) on periderm formation. On the other hand, *Aloe ciliaris* pro-

duces some of the strongest callus developments seen in this survey, and *Sansevieria* readily forms roots and stems from pieces of leaves, although it does not form callus.

In general, leaves of the sclerophyllous type, even in damp atmospheres, appear to form periderm rather than callus, and of this behavior *Citrus aurantium* is a good example. Here again exceptions are found in *Nerium oleander*, *Vinca minor*, and *Hedera helix*, which form very abundant callus.

The leaves of succulents usually tend to form periderm on wounded surfaces unless kept very moist, and then they rot without showing any reaction. Several species other than those listed in Table I have been observed; they follow the same behavior pattern as those listed. However, *Aloe ciliaris* has succulent leaves, as does *Hoya carnosa* also, yet both these callus very well.

Some leaves form callus abundantly on petioles, but none on portions of the leaf blade; others show exactly the opposite procedure. It must be recognized, too, that these trials are not absolutely conclusive, since the conditions may not have been optimum for all leaves. These results do not always agree with those reported for the reaction of wounds on leaves still attached to their stems. For example, Küster (17) reports that the cells bordering the lacunae in Nymphaeaceae produce threadlike outgrowths in wounds, but no such reaction has ever been seen by the author.

The extent to which periderm formation followed wounding in these leaves was not investigated, but that periderm formation may follow the production of callus is shown in Figure 4C. Rodger (34) found that actual submergence in water did not prevent the development of periderm in wounded leaves, though it did inhibit cell outgrowth.

The experimental production of cell outgrowth in wounded leaves

In a previous paper (19) the author described the separation of the lower epidermis and a hypodermal layer from the mesophyll in mature leaves of *Mitchella repens*. Since these layers are normally separated from the spongy mesophyll and can be removed without injury to that tissue, this species appeared to be well suited to attempts to induce cell proliferation from exposed but unwounded tissues. In Table I *Mitchella repens* is recorded with a rating of 2, because it does form outgrowths along the midrib and around the

edges of leaves from which the lower epidermis has been cut. It also forms callus in response to wounding in any part of the leaf, but the unwounded spongy mesophyll normally shows no cell outgrowth.

The lower epidermis was removed from leaves of *Mitchella*, which were then laid in moist chambers with the upper epidermis in contact with moist filter paper. Several leaves were kept in this condition as controls. On others drops of synthetic heteroauxin¹ solution — 0.5 mg. auxin to 100 ml. of water — were placed. In Figure 5A

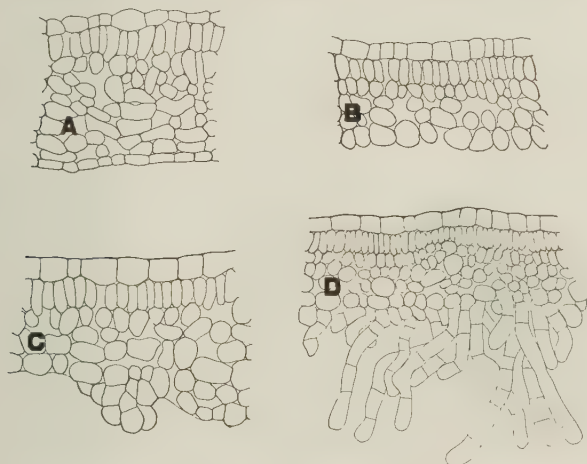


FIG. 5. The production of cell outgrowths in leaves of *Mitchella repens* by the application of heteroauxin. The figures were drawn from prepared slides with the aid of a Bausch and Lomb projection apparatus. A. Cross section of a normal leaf. B. Cross section of a leaf from which the lower epidermis and a hypodermal layer have been removed. C. Cross section of a leaf from which the lower epidermis and a hypodermal layer have been removed, showing one of the occasional outgrowths produced without the application of auxin. D. Cross section of a leaf similar to that shown in C, but cut through the region on which a drop of heteroauxin had stood.

is shown a cross section of a normal leaf of *Mitchella repens*; in Figure 5B, a cross-section view of a leaf after the lower epidermis and the hypodermal layer had been removed. The drops of heteroauxin solution were placed on exposed cells, such as are shown in this figure.

¹ The heteroauxin was supplied by Professor F. W. Went of the California Institute of Technology.

The control leaves showed no apparent outgrowths under a binocular microscope with a magnification of 30 diameters. Sections of these leaves exhibited no change over the greater part of the surface, but in some places small outgrowths appeared, of which that shown in Figure 5C is typical. It was impossible to tell whether or not slight injuries were responsible for these proliferations.

Under the vascular bundles little outgrowth was seen, but a strong development of periderm was apparent. Periderm was not found anywhere except in the vicinity of vascular bundles. Cell outgrowths were abundant around the margins of the leaves where the lower epidermis had been cut away.

The treated leaves showed outgrowths only along the midrib and around the margins until the drops of heteroauxin solution had disappeared. Then the whole of each area which had been covered by a drop of solution began to form outgrowths. These developed until each area became a sort of plateau, which rose above the level of the surrounding tissue by an amount equal to, or greater than, the entire thickness of the original leaf. At first these flat disks were made up of scattered chains of glistening white cells, but later the chains became much more closely packed together. The cells gradually developed chlorophyll until they became of the same color as the normal undisturbed mesophyll which surrounded them. Figure 5D shows a cross section of a leaf through a part of one of the areas over which a drop of heteroauxin solution had stood. The contrast with the proliferation on a control leaf (Fig. 5C) is obvious.

The experiment with the water solution of auxin was repeated with precisely the same result. Later, experiments were performed with the same method, but with lanolin impregnated with the synthetic heteroauxin — 0.5 mg. heteroauxin to 100 cc. of lanolin. Small dots of lanolin were applied to the exposed mesophyll of the leaves.

The lanolin caused noticeable injury to the mesophyll cells to which it was applied, but beyond the injured areas rings of cell outgrowths appeared which were identical in structure and development with those shown in Figure 5D.

Leaves of *Coreopsis lanceolata* were tested with heteroauxin in lanolin applied to leaves from which the lower epidermis had been peeled. As a result, the cells immediately under the lanolin became

discolored, but showed some swelling. Around the discolored areas a strong development of cell outgrowths took place. Untreated control leaves and untreated areas on the experimental leaves produced scattered small proliferations.

Callus development on wounded stem tissues

The stems of a number of different plants were cut into pieces one or two inches in length. These segments were then cut so as to expose the different layers of the cortex or the bark, the cambium on the inside of the cortex or the bark, the cambium on the surface of the xylem, and the pith. In addition to the exposure of the ray initials in the cambium, the twigs were split so as to expose the rays in radial section. Woody plants were generally represented by twigs one, two, or three years old.

The stem segments were enclosed in damp chambers and in contact with moist paper toweling. The results of the treatment are given in Table II.

TABLE II

NATURE AND EXTENT OF CELL OUTGROWTHS ON WOUNDED STEMS

B = outgrowth from cambium on inside of cortex or bark

C = outgrowth from cortex or bark

X = outgrowth from cambium on xylem

R = outgrowth from rays

E = outgrowth from cut end of stem

P = outgrowth from pith

Rt = adventitious roots formed

O = no outgrowth of any kind

<i>Species</i>	<i>Cell outgrowth</i>	<i>Species</i>	<i>Cell outgrowth</i>
<i>Acorus calamus</i>	O	<i>Botrychium virginia-</i> <i>num</i>	O
<i>Agropyron repens</i> (aerial stem)	O	<i>Brassica nigra</i>	B, C, E, P, X
<i>Agropyron repens</i> (rhizome)	O	<i>Celastrus scandens</i> . .	B, E, X
<i>Ailanthus glandulosa</i>	E, B, C, X	<i>Chenopodium album</i> . .	B, C, E, P, X
<i>Alnus incana</i>	B, C, X	<i>Comandra umbellata</i> . .	E
<i>Amelanchier spicatum</i>	E	<i>Cornus circinata</i> . . .	B, X
<i>Antennaria</i> sp.	C	<i>Corylus americana</i> . . .	O
<i>Apocynum cannabi-</i> <i>num</i>	C, E, X	<i>Crataegus</i> sp.	B, E, P, X
<i>Arctostaphylos uva-</i> <i>ursi</i>	B, C, X	<i>Cynoglossum vulgare</i> . .	C, E, P
<i>Asclepias syriaca</i>	C, X	<i>Decodon verticillata</i> . .	B, C, X
<i>Aster laevis</i>	C, P, X	<i>Diervilla lonicera</i> . . .	B, C, X
		<i>Eleocharis rostellata</i> . .	O
		<i>Equisetum hiemale</i> . .	Rt.
		<i>Erigeron canadensis</i> . .	B, C, E, R, X

<i>Species</i>	<i>Cell outgrowth</i>	<i>Species</i>	<i>Cell outgrowth</i>
<i>Forsythia suspensa</i> ..	B, C, E, X	<i>Populus grandiden-</i>	
<i>Fragaria virginica</i> ...	E	<i>tata</i>	B, C, E, X
<i>Fraxinus americana</i> ..	B, E, X	<i>Populus tacamahaca</i> ..	B, C, E, P, X
<i>Geum rivale</i>	O	<i>Populus tremuloides</i> ..	B, C, E, X
<i>Hedera helix</i>	C, P	<i>Prunus pennsylvanica</i> ..	B, C, E
<i>Helianthus annuus</i> ..	C, X	<i>Prunus pumila</i>	O
<i>Hippuris vulgaris</i> ...	E	<i>Prunus serotina</i>	B, C, X
<i>Humulus lupulus</i>		<i>Prunus virginiana</i>	B, C, X
(aerial stem)	B, C, E, P, X	<i>Pteris aquilina</i>	O
<i>Humulus lupulus</i>		<i>Pyrola elliptica</i>	O
(underground stem) ..	B, C, Rt, X	<i>Pyrus malus</i>	B, C, X
<i>Ilex verticillata</i>	O	<i>Quercus borealis</i>	B, R
<i>Lepidium virginicum</i> ..	E, P	<i>Radicula aquatica</i> ...	B, C, E, P, X
<i>Ligustrum vulgare</i> ..	P	<i>Rhus typhina</i>	C
<i>Lychnis alba</i>	O	<i>Ribes aureum</i>	P
<i>Lycium halimifolium</i> ..	C, P, Rt	<i>Rubus allegheniensis</i> ..	B, C, X
<i>Lycopersicon esculen-</i>		<i>Rubus occidentalis</i> ..	E, X
<i>tum</i>	B, C, E, X	<i>Rumex acetosella</i>	E
<i>Lycopodium compla-</i>		<i>Salix longifolia</i>	B, C, E, X
<i>natum</i>	O	<i>Salix lucida</i>	B, C, E, X, R
<i>Lycopodium annoti-</i>		<i>Sambucus canadensis</i> ..	B, C, E, X
<i>num</i>	O	<i>Sambucus racemosa</i> ..	B, C, E, X
<i>Lysimachia nummu-</i>		<i>Saponaria officinalis</i> ..	B, C, X
<i>laria</i>	Rt	<i>Sarracenia purpurea</i> ..	O
<i>Maianthemum cana-</i>		<i>Scirpus americanus</i> ..	O
<i>dense</i>	O	<i>Scirpus validus</i>	O
<i>Malva rotundifolia</i> ..	B, C, E	<i>Solanum Dulcamara</i> ..	B, C, E, P, R, X
<i>Myriophyllum hetero-</i>		<i>Taxus canadensis</i> ...	B, X
<i>phyllum</i>	O	<i>Tilia americana</i>	B, C, E, X
<i>Nemopanthus mu-</i>		<i>Tsuga canadensis</i> ...	B, X
<i>cronata</i>	C	<i>Verbascum thapsus</i> ..	O
<i>Oenothera biennis</i> ...	B, C, E, X	<i>Veronica americana</i> ..	O
<i>Phaseolus vulgaris</i> ..	C, P	<i>Viburnum acerifolium</i> ..	C, X
<i>Pinus strobus</i>	B, C, X	<i>Viburnum cassinoides</i> ..	C, X
<i>Polygonum amphi-</i>		<i>Vinca minor</i>	B, C, P, X
<i>bium</i>	O	<i>Vitis Vulpina</i>	B, C, E, X

Only a few of the Pteridophyta were studied, but none of these produced cell proliferations. *Pteris aquilina* always perished without showing any change. Species of *Equisetum* produce no cell outgrowths, but root readily in water and produce shoots from preformed buds, as shown by Schaffner (35) and by the writer in unpublished studies. *Botrychium virginianum* forms no callus, but in nature it propagates by root sprouts, a fact generally known (Campbell, 3). Species of *Lycopodium* do not form callus, but form roots sparsely on cuttings (Barrows, 2; Roberts and Herty, 3). Altogether the Pteridophyta may be considered unregenerative.

The stems of monocotyledonous plants, as represented in this list, are all unable to form callus.

Nearly all the herbaceous species are able to sprout from crowns or from rhizomes and are regarded by the author (25) as types specialized in vegetative reproduction, and, as usually appears to be true of such types, they have little or no power of regeneration. Such a notorious weed as *Agropyron repens* reproduces itself vegetatively only by the growth of preformed buds and will not regenerate at all.

Several woody plants, *Ribes aureum*, *Rhus typhina*, *Ligustrum vulgare*, *Ilex verticillata*, *Prunus pumila*, *Viburnum acerifolium*, *Viburnum cassanoides*, and *Nemopanthus mucronata* were less reactive than most of the trees. These are all shrubby plants which sprout readily from the roots and may be regarded as types specialized for vegetative reproduction. *Prunus pumila* offers a decided contrast to the tree cherries. It must not be overlooked that *Sambucus canadensis*, *Salix lucida*, and *Solanum Dulcamara* are among the most active in the formation of cell outgrowths, yet all sprout readily from roots, as do the poplars, in which the abundant formation of callus has been studied by Simon (38).

On the wood of several species the cambium did not produce outgrowths, but callus developed from the ends of the rays. In *Hevea brasiliensis*, the Pará rubber tree, it has often been noted by the writer that new bark may be regenerated over cambium, which has been killed by drying, by outgrowths from the ends of the rays. This regeneration in *Hevea* has been described by Sharples and Gunnery (37). Similar behavior in *Acer rubrum* has been observed by the author.

DISCUSSION

The similarity of the cells formed in lenticular outgrowths, intumescences, tyloses, certain types of galls, *Perldrüsen*, and callus suggests the presence of some basic similarity in the stimulus which is directly responsible for their production. The phenomenon represented by the change from normal, apparently mature cells into cells capable of assuming unusual shapes and sizes or even into meristematic cells capable of repeated division, is at least a puzzling one.

Intumescences have been shown to be due to a variety of different causes. The writer has found very recently that intumescences on

leaves of *Populus grandidentata* may be produced by applications of heteroauxin.

Haberlandt (7) noted the development of cell reactions in the neighborhood of phloem elements, and assumed the presence of a lepto-hormone produced in the phloem. The work of Went (48) and others on the plant growth hormone, auxin, shows that this substance is transported in the phloem, and this fact may account for the cell behavior noted by Haberlandt, as well as for similar reactions observed in leaves in this study. Recent observations by Merry (31) in the author's laboratory prove that periderm formation may take place in tissues which have no phloem. He found that the endosperm of *Crinum asiaticum*, which is a very homogenous tissue, forms periderm normally over its surface, which is not protected by a seed coat, and also on the surfaces of wounds.

Whether the wounding of tissues produces a hormone, as Haberlandt (8) believes, may be questioned. Many wounded tissues do not react at all, as this study shows; and we know that intumescences, tyloses, etc., may be formed without the wounding of any cells. The reaction of *Mitchella repens* to the application of heteroauxin shows that this substance may cause cell outgrowths to be formed on unwounded, but exposed, tissues. Whether the extracts which Wehnelt (47) found capable of producing cell division in the tissue of bean pods contained auxin remains to be determined.

The production of intumescences in *Mitchella repens* and *Hieracium venosum* (23) in response to wounding might be interpreted as an indication of the presence of a wound hormone, but other explanations are possible. The writer believes that, in general, wounding merely releases the pressure which tends to prevent the swelling of the cells, which is able sometimes to take place in spite of this pressure, as intumescence formation shows. Cell projection into protoxylem lacunae, the occurrence of *false tyloses* in resin ducts, and probably tyloses themselves are examples of the tendency of cells to expand when pressure is removed.

Inasmuch as auxin appears to be needed for cell wall growth — and practically all the cell outgrowths which have been mentioned here involve some increase in cell size though they may include cell division also — it appears that all these growths, lenticular outgrowths, intumescences, galls, *Perldrüsen*, tyloses, etc., are effects

of the action of auxin. The wide differences in causal agencies seem irreconcilable, but may be regarded as affecting the production, transport, localization of auxin, or perhaps even the sensitivity of the cells to the action of auxin.

The undoubted effects of water supply, temperature, oxygen tension, etc., emphasized by Swingle (42), are admittedly important, but are believed to be contributory to the final action of the growth hormone which causes the immediate increase in the area of the cell wall. Therefore the unity of behavior in all the different species in producing callus, galls, etc., exists only in the final stages of the various processes, and the variety of treatments which can produce such effects remains as great as ever.

The relationship of callus to regeneration is not clear. Certainly callus is not needed for the formation of adventitious roots, for *Coleus* leaves do not callus at all, yet they form roots very readily. Nor do pieces of embryo which grow into plants in tissue cultures (26) show a development of callus. Yet in *Populus nigra* var. *italica* the calluses on twigs give rise to buds in great numbers and, in general, the formation of callus precedes the regeneration of buds. So far as regeneration of tissues in culture is concerned, those plants which form no cell outgrowths on wounds probably will not prove good subjects for experiment.

Some plants appear to contain *totipotent* cells in their tissues, whatever their age, and these are capable of regeneration. Others show such cells only in earlier stages of their growth. In a survey like the present one the proper stage may not have been selected in many species.

Whether unreactive species are such merely because their cells lack auxin for growth is questionable. Apparently this is true in some cases, for the cells nearest a source of auxin show best growth (in the neighborhood of vascular bundles, on the inside of the phloem, etc.). The writer is inclined to believe that many cells may be supplied with auxin without causing any reaction, because these cells are too old or are otherwise inhibited. From numerous indications there is some evidence that auxin will produce its effects, when applied experimentally, only in those tissues which normally show at least slight effects without additional auxin.

The idea is expressed here that the plant growth hormone is probably the immediate cause of all types of cell outgrowth, callus,

intumescences, galls, tyloses, etc., but there is no implication that this hormone will produce outgrowth in all tissues, or that there are not numerous other factors which exercise an influence equally great, if not greater, on these processes.

SUMMARY

1. The ability of numerous species of plants to form cell outgrowths from wounded leaves and stems in damp atmospheres has been investigated and the results are given in tabular form.

2. The morphology of the cell outgrowths is briefly treated.

3. Members of the Pteridophyta do not show callus formation on wounds.

4. Monocotyledonous plants usually show little or no callus formation, but some species are notable exceptions.

5. Sclerophyllous and succulent species, in general, tend to form periderm rather than callus.

6. Leaves of a number of species form adventitious roots, although they do not form callus.

7. The majority of dicotyledonous leaves fail to form cell outgrowths.

8. Cell outgrowths have been produced on leaves of *Mitchella repens* and *Coreopsis lanceolata* by the application of heteroauxin.

9. Most dicotyledonous stems form callus on wounds in some of their tissues.

10. The dicotyledonous stems which produce no callus are generally those of species which have a specialized type of vegetative reproduction.

11. Callus formation in stems is usually strongest on the inside of the phloem.

12. Usually plants with great regenerative capacity show the strongest development of callus, but certain species which regenerate readily form little or no callus.

13. It is suggested that all outgrowths which involve increase in cell size (galls, intumescences, tyloses, lenticular outgrowths, *Perl-drüsen*, etc.) may be alike in that auxin is the immediate cause of cell enlargement. They may differ widely in respect to other factors which play important parts in their incidence and development.

LITERATURE CITED

1. ATKINSON, G. F. 1893. Oedema of the Tomato. Bull. Cornell Agric. Exper. Sta., No. 53: 1-108.
2. BARROWS, F. L. 1935. Propagation of Lycopodium. I. Spores, Cuttings and Bulbils. Contrib. Boyce Thompson Inst., 7: 267-294.
3. CAMPBELL, D. H. 1905. The Structure and Development of Mosses and Ferns. vi + 657. Macmillan, London and New York.
4. DALE, E. 1901. Investigations on Abnormal Outgrowths or Intumescences on *Hibiscus vitifolius* Linn. Phil. Trans. Roy. Soc. London. B, 194: 163-182.
5. DEVAUX, M. H. 1900. Recherches sur les lenticelles. Ann. sci. nat. bot., Sér. 8, 12: 1-240.
6. GERRY, E. 1914. Tyloses, Their Occurrence and Practical Significance in Some American Woods. Journ. Agric. Res., 1: 445-469.
7. HABERLANDT, G. 1913. Zur Physiologie der Zellteilung. Sitzungsber. der könig.-preuss. Akad. Wiss., pp. 318-345.
8. ——— 1922. Über Zellteilungshormone und ihre Beziehungen zur Wundheilung, Befruchtung, Parthenogenesis und Adventivembryonie. Biol. Zentralbl., 42: 145-172.
9. HAHN, G. G., HARTLEY, C., AND RHOADES, A. 1920. Hypertrophied Lenticels on the Roots of Conifers and Their Relation to Moisture and Aeration. Journ. Agric. Res., 20: 253-266.
10. HARVEY, R. B. 1918. Hardening Process in Plants and Developments from Frost Injury. Journ. Agric. Res., 15: 83-112.
11. HEILBRONN, A. 1910. Apogamie, Bastardierung und Erblchkeitsverhältnisse bei einigen Farnen. Flora, 101: 1-42.
12. HOLDEN, H. S. 1916. Further Observations on the Wound Reactions of the Petioles of *Pteris aquilina*. Ann. Bot., 30: 127-133.
13. KLEIN, C. 1923. Zur Ätiologie der Thyllen. Zeitschr. Bot., 15: 417-439.
14. KÜSTER, E. 1903. Über experimentelle erzeugte Intumescenzen. Ber. deut. bot. Gesell., 21: 452-458.
15. ——— 1906. Histologische und experimentelle Untersuchungen über Intumescenzen. Flora, 96: 527-537.
16. ——— 1911. Die Gallen der Pflanzen. x + 437. S. Hirzel, Leipzig.
17. ——— 1916. Pathologische Pflanzenanatomie. xi + 447. G. Fischer, Jena.
18. LA RUE, C. D. 1930. Regeneration in Some American Mosses. Pap. Mich. Acad. Sci., Arts and Letters, 11 (1929): 225-241.
19. ——— 1931. The Water Supply of the Epidermis of Leaves. *Ibid.*, 13 (1930): 131-139.
20. ——— 1933a. Regeneration in Mutilated Seedlings. Proc. Nat. Acad. Sci., 19: 53-63.

21. LA RUE, C. D. 1933b. Intumescences on Poplar Leaves. I. Structure and Development. *Am. Journ. Bot.*, 20: 1-17.
22. ——— 1933c. Intumescences on Poplar Leaves. II. Physiological Considerations. *Ibid.*, 20: 159-175.
23. ——— 1933d. Intumescences on Leaves of *Eucalyptus cornuta*, *E. coccifera*, *Hieracium venosum*, *Mitchella repens*, and *Thurberia thespesioides*. *Phytopath.*, 23: 128-289.
24. ——— 1935. Regeneration in Monocotyledonous Seedlings. *Am. Journ. Bot.*, 22: 486-492.
25. ——— 1936a. Vegetative Reproduction in *Eleocharis rostellata*. *Pap. Mich. Acad. Sci., Arts and Letters*, 21 (1935): 105-117.
26. ——— 1936b. Tissue Cultures of Spermatophytes. *Proc. Nat. Acad. Sci.*, 22: 201-209.
27. ——— 1936c. The Growth of Plant Embryos in Culture. *Bull. Torr. Bot. Club*, 63: 365-382.
28. ——— AND MACNEILL, M. 1934. The Behavior of Decapitated Seedlings. *Pap. Mich. Acad. Sci., Arts and Letters*, 19 (1933): 113-131.
29. LAWTON, E. 1932. Regeneration and Induced Polyploidy in Ferns. *Am. Journ. Bot.*, 19: 303-333.
30. MASSART, J. 1898. La Cicatrisation chez les végétaux. *Mém. couronnés Acad. roy. sci. belgique*, 57: 2-68.
31. MERRY, J. 1936. Formation of Periderm in the Endosperm of *Crinum asiaticum*. *Pap. Mich. Acad. Sci., Arts and Letters*, 22 (1935): 159-164.
32. PRIESTLEY, J. H., AND WOFFENDEN, L. M. 1922. Physiological Studies in Plant Anatomy. V. Causal Factors in Cork Formation. *New Phytologist*, 21: 252-268.
33. ROBERTS, E. A., AND HERTY, S. D. 1934. *Lycopodium complanatum* var. *flabelliforme* Fernald: Its Anatomy and a Method of Vegetative Propagation. *Am. Journ. Bot.*, 21: 688-697.
34. RODGER, E. A. 1933. Wound Healing in Submerged Plants. *Am. Mid. Nat.*, 14: 704-713.
35. SCHAFFNER, J. H. 1931. Propagation of Equisetum from Sterile Aerial Shoots. *Bull. Torr. Bot. Club*, 58: 531-535.
36. SCHILLING, E. 1915. Über hypertropische und hyperplastische Gewebeswucherungen an Sprossachsen, verursacht durch Paraffine. *Jahrb. wiss. Bot.*, 55: 177-258.
37. SHARPLES, A., AND GUNNERY, H. 1933. Callus Formation in *Hibiscus rosasinensis* L. and *Hevea brasiliensis* Muell. Arg. *Ann. Bot.*, 47: 827-839.
38. SIMON, S. 1908. Experimentelle Untersuchungen über die Differenzierungsvorgänge am Kallusgewebe von Holzgewächsen. *Jahrb. wiss. Bot.*, 45: 351-478.
39. SMITH, E. F. 1920. An Introduction to Bacterial Diseases of Plants. xxx + 688. W. B. Saunder Co., Philadelphia and London.

40. SORAUER, P. 1899. Über Intumescenzen. Ber. deut. bot. Gesell., 17: 456-460.
41. ——— 1909. Handbuch der Pflanzenkrankheiten. 3. Auf., Bd. 1. xvi + 891. Paul Parey, Berlin.
42. SWINGLE, C. F. 1929. A Physiological Study of Rooting and Callusing in Apple and Willow. Journ. Agric. Res., 39: 81-128.
43. VÖCHTING, H. 1908. Untersuchungen zur experimentellen Anatomie und Pathologie des Pflanzenkörpers. I. vii + 318. 20 pls. H. Laupp'schen Buchhandl., Tübingen.
44. VON SCHRENK, H. 1905. Intumescences Formed as a Result of Chemical Stimulation. Rep. Missouri Bot. Gard., 16: 125-148.
45. WALLACE, R. H. 1926. The Production of Intumescences upon Apple Twigs by Ethylene Gas. Bull. Torr. Bot. Club, 53: 385-401.
46. WALTER, HEINRICH. 1921. Über Perldrüsenbildung bei Ampelideen. Flora, 114: 187-231.
47. WEHNELT, B. 1927. Untersuchungen über das Wundhormon der Pflanzen. Jahrb. wiss. Bot., 66: 773-813.
48. WENT, F. W. 1935. Auxin, the Plant Growth-Hormone. Bot. Rev., 1: 162-182.
49. WHITE, P. R. 1934. Potentially Unlimited Growth of Excised Tomato Root Tips in a Liquid Medium. Plant Physiol., 9: 585-600.
50. WISNIEWSKI, P. 1910. Über Induktion von Lenticellenwucherungen bei Ficus. Bull. Acad. Sci. Cracovie, 5: 359-367.
51. WOLF, F. A. 1918. Intumescences, with a Note on Mechanical Injury as a Cause of Their Formation. Journ. Agric. Res., 13: 253-259.
52. WORONIN, H. 1908. Apogamie und Aposporie bei einigen Farnen. Flora, 98: 101-162.
53. WYLIE, R. B. 1930. Cicatrization of Foliage Leaves. I. Wound Responses of Certain Mesophytic Leaves. Bot. Gaz., 90: 260-278.

FRESH-WATER ALGAE FROM TEXAS *

LOIS C. LILLICK

DURING the spring of 1933 a collection of fresh-water Algae was made, primarily in the southern Rio Grande region of Texas, by Dr. Elzada U. Clover, of the University of Michigan. The collection represents about forty samples from ten different localities in the state, collected between the latter part of February and the end of May.

A number of groups are represented, the majority of the forms being members of the Chlorophyceae and Cyanophyceae. Two rather unusual species of fresh-water Rhodophyceae have been identified by Dr. H. Skuja (of Riga, Latvia): *Batrachospermum occidentale*, a new form, the description of which has not as yet been published by Dr. Skuja; and *Thorea andina* Moeb. et Lagerh., which was collected from Comal Springs at New Braunfels. This plant, together with *Hildenbrandia rivularis* (Lieb.) J. Ag., was collected from this location and distributed in the Phycotheca Boreali-Americana of Collins, Holden, and Setchell (numbers 740 and LXXIV), and both have been rediscovered at the identical location by Dr. Clover. Desmids in the present collection are extremely rare and have been omitted from consideration here. Diatoms, though very abundant and even dominant in some samples, have likewise been omitted.

The localities from which the collections were gathered are of some interest. The largest number of samples were taken in February, 1933, from the springs at the head of the San Marcos River, rising from limestone hills. The Comal Springs, at the head of the Comal River, New Braunfels, Comal Co., likewise fed from limestone hills, provides an interesting habitat in that the water is thermal. Collections were made here in February. From a water hole on a ranch in Brooks Co., several miles north of the Hidalgo

* Papers from the Department of Botany of the University of Michigan, No. 560.

Co. line, in a sandy, alkaline area, other collections were made in April. Among these was a new variety of *Oedogonium*. Lake La Joya, in Hidalgo Co., yielded some very interesting collections in February. The lake is a small one, covering an area of about one-half square mile, fed by flood waters from the Rio Grande and by other waters from the surrounding gravel and limestone hills. At times it dries up entirely, though there is usually some water standing in it. From this locality have come a new species of *Gloeotrichia* and one of *Oedogonium*. A water hole on "El Por Venir" Ranch, northwest of Mission, in Hidalgo Co., yielded other material (April). The land in this section is very level, and the soil alkaline to neutral. At Raymondville, Willacy Co., the land is low, the soil an acid sandy loam. Since the water holes from which collections were made (May) are within twenty miles of the ocean, there is a possibility of salt water being blown into them by hurricanes. Between San Benito and Brownsville, Cameron Co., collections were made (March) from low marshy places filled in by flood water from the Rio Grande, areas which may dry up at times. From Mercedes, Hidalgo Co., as well as from the San Benito area, has come a rare species of *Nitella*. This has been found most abundantly in barrow pits, which are shallow depressions at the sides of a canal and which are filled by seepage from the canal.

Till the present time there have been almost no published records of Algae from Texas. A few specimens have been distributed in exsiccatae, as mentioned in the *Phycotheca Boreali-Americana* and in Tilden's *American Algae*, Century VII, Fascicle I, 1909. In Tilden's *Minnesota Algae*, Volume I, seven species and one variety of Cyanophyceae are listed as occurring in Texas. Smith (1933) mentions as occurring in the fruiting condition *Dichotomosiphon tuberosa* (A. Braun) Ernst, the specimens of which have been distributed in the *Phycotheca Boreali-Americana*, number 764. Aside from these, there seem to be no other published records of Algae from the state. Since the present small collection has yielded certain forms with extremely interesting geographical distribution as well as a few new forms, it would be expected that a more extensive survey of the field might prove very profitable. Of especial interest might be collections from the salt-marsh areas, and from the lower parts of the rivers which empty into the Gulf of Mexico.

LIST OF SPECIES

CYANOPHYCEAE

CHROOCOCCACEAE

- APHANOCAPSA GREVILLEI (Hass.) Roth. — Brooks Co.
APHANOCAPSA MONTANA Cramer. — Mission.
CHROOCOCCUS MINUTUS (Kütz.) Näg. — San Marcos, scarce.
COELOSPHAERIUM DUBIUM Grun. — Lake La Joya; Raymondville,
very abundant in plankton, forming almost a pure culture.
GLOEOCAPSA ATRATA (Turp.) Kütz. — Brooks Co.
GOMPHOSPHAERIA APONINA Kütz.
MERISMOPEDIA PUNCTATA Meyen. — San Marcos; Lake La Joya;
Raymondville; Comal Springs.
MERISMOPEDIA TENUISSIMA (Kütz.) Näg. — Lake La Joya, scarce.
MICROCYSTIS MARGINATA (Menegh.) Kütz. — Lake La Joya; Comal
Springs.

PLEUROCAPSACEAE

- XENOCOCCUS CHROOCOCCOIDES Fritsch. — Comal Springs, on *Cladophora glomerata*.

CHAMAESIPHONACEAE

- CHAMAESIPHON CONFERVICOLA A. Braun. — Comal Springs, epiphytic
on *Cladophora glomerata*.

OSCILLATORIACEAE

- LYNGBYA SP. — San Marcos, scarce.
OSCILLATORIA BREVIS (Kütz.) Gom. — Raymondville.
OSCILLATORIA CHALYBEA Mert. — Rio Hondo.
OSCILLATORIA PRINCEPS Vauch. — San Marcos, very abundant;
Raymondville, scarce; Comal Springs; Rio Hondo.
PHORMIDIUM AUTUMNALE (C. Ag.) Gom. — San Marcos.
PHORMIDIUM TINCTORIUM Kütz. — Comal Springs.
PHORMIDIUM UNCINATUM Gom. — San Marcos.
SPIRULINA MAJOR Kütz. — Lake La Joya.

NOSTOCACEAE

- ANABAENA CONTORTA Bachm. (Pl. XVIII, Fig. 1). — San Benito;
formerly reported from Greenland.

NODULARIA HARVEYANA Thur. — The form comes nearest to and probably belongs to this species.

NOSTOC LINKIA (Roth) Born.

SCYTONEMATACEAE

CAMPTYLONEMA INDICUM Schmidle. — Rio Hondo; formerly reported from Bombay.

RIVULARIACEAE

CALOTHRIX COLUMBIANA G. S. West. — This form probably belongs here.

CALOTHRIX SCYTONEMICOLA Tilden. — Probably. Lake La Joya.

CALOTHRIX STELLARIS Born. & Flah. — San Benito.

GLOEOTRICHIA HETEROCYSTOSA, sp. nov. — Lake La Joya.

LEPTOCHAETE CRUSTACEA (Rab.) Kirchn. — Mission.

RHODOPHYCEAE

BATRACHOSPERMACEAE

BATRACHOSPERMUM OCCIDENTALE Skuja Ms. — San Marcos.

THOREACEAE

THOREA ANDINA Moeb. & Lagerh. — Comal Springs.

SQUAMARIACEAE

HILDENBRANDIA RIVULARIS (Lieb.) J. Ag. — Comal Springs.

HETEROKONTAE

TRIBONEMATACEAE

BUMILLERIA EXILIS Klebs. — San Marcos, a little large.

CHLOROPHYCEAE

VOLVOCACEAE

EUDORINA ELEGANS Ehr.

EUDORINA ILLINOISENSIS Pascher. — Lake La Joya.

PANDORINA MORUM (O. F. Müll.) Bory. — Lake La Joya; Raymondville.

PALMELLOCOCCACEAE

SPHAEROCYSTIS SCHROETERI Chod. — San Marcos, extremely rare.

TETRASPORACEAE

TETRASPORA GELATINOSA (Vauch.) Desv. — Brooks Co. Probably this species, but poorly preserved.

CHAETOPHORACEAE

STIGEOCLONIUM GLOMERATUM (Hazen) Collins. — San Benito.

CLADOPHORACEAE

CLADOPHORA SP. — Comal Springs.

CLADOPHORA GLOMERATA (L.) Kütz. — Comal Springs.

PITHOPHORA VARIANS Wille. — San Benito.

OEDOGONIACEAE

BULBOCHAETE SP. — San Marcos.

OEDOGONIUM SPP. — San Marcos; Lake La Joya; San Benito; Alamo.

OEDOGONIUM CLOVERAE, sp. nov. — Lake La Joya; San Benito (?).

OEDOGONIUM MULTISPORUM Wood. — Raymondville.

OEDOGONIUM PRINGSHEIMII var. NORDSTEDTII Wittr. — San Benito.

OEDOGONIUM RUFESCENS var. FRUTICOSUM, var. nov. — Brooks Co.

SCHIZOMERIDACEAE

SCHIZOMERIS LEIBLEINII Kütz. — Raymondville, very rare.

HYDRODICTYACEAE

HYDRODICTYON RETICULATUM (L.) Lagerh. — San Marcos; Lake La Joya.

PEDIASTRUM BORYANUM (Turp.) Lagerh. — San Marcos; Lake La Joya.

PEDIASTRUM DUPLEX var. GENUINUM A. Braun. — Raymondville.

PEDIASTRUM DUPLEX var. RETICULATUM Lagerh. — Raymondville.

PEDIASTRUM SIMPLEX (Meyen) Lemm. — Raymondville.

PEDIASTRUM SIMPLEX var. DUODENARIUM (Bail.) Rab. — Raymondville.

COELASTRACEAE

COELASTRUM MICROPORUM Näg. — Raymondville.

OÖCYSTACEAE

OÖCYSTIS MARSONII Lemm. — San Marcos. Probably; extremely rare.

OÖCYSTIS RUPESTRIS Kirchn. — Brooks Co.

TETRAËDON CRASSISPINUM (Reinsch) Wille. — San Marcos.

SCENEDESMACEAE

SCENEDESMUS ACUMINATUS Lagerh. — Raymondville.

SCENEDESMUS BIJUGA (Turp.) Lagerh. — San Marcos; Lake La Joya.

SCENEDESMUS BIJUGA var. SERIATA Chod. — San Marcos.

SCENEDESMUS QUADRICAUDA (Turp.) Bréb. — San Marcos; Lake La Joya.

VAUCHERIACEAE

VAUCHERIA SPP. — San Marcos; San Benito.

ZYGNEMATACEAE

MOUGEOTIA SP. — San Marcos; Lake La Joya.

MOUGEOTIA SPHAEROCARPA Wolle. — San Marcos; Lake La Joya.

SPIROGYRA SP. — Raymondville.

SPIROGYRA DUBIA Kütz. — Lake La Joya.

ZYGNEMA SP. — San Marcos.

CHAROPHYCEAE

CHARA SP. — San Marcos.

CHARA VULGARIS Linn. — Brooks Co.

NITELLA PRAELONGA A. Br. — Near San Benito; Mercedes.

DINOPHYCEAE

GLENODINIUM SP. — Brooks Co.

PERIDINIUM SP. — Brooks Co.

EUGLENOPHYCEAE

EUGLENA PROXIMA Dang. — Infected with *Polyphagus Euglenae*.

PHACUS PLEURONECTES (O. F. Müll.) Duj. — San Benito.

***Gloeotrichia heterocystosa*, sp. nov.**

(Pl. XVIII, Figs. 4-6)

Plant mass an expanded, shapeless, gelatinous stratum, frequently several centimeters in extent; filaments originally radiating from

a common center, later scattered irregularly in the gelatinous matrix; old trichomes up to 1 mm. or more long, tapering slightly, not ending in a hair, but hairs frequently present in young filaments; sheaths colorless, widely divergently saccate, sometimes showing faint laminations, rarely extending much beyond the resting spores; false branching absent or very rare; cells at the base 6–10 μ wide, 0.5–1 diameter long, gradually narrowing toward the tip and increasing in length to as much as four or more times the width, constricted at the cross walls, the contents smooth or slightly granular, pseudovacuoles absent, color aeruginose; hormogonia of many cells a frequent means of reproduction; resting spores normally straight, cylindrical or swollen at the base, 25–65 μ long, 8–21 μ wide, the outer membrane smooth, colorless or rarely faintly yellow in older filaments, single or, less commonly, paired when sometimes separated by a heterocyst, rarely intercalary; heterocysts usually terminal and spherical, rarely ovoid, flattened where in contact with the resting cell, 8–12 μ in diameter, 1–several together; intercalary heterocysts usually compressed, 1–several together, usually 2–3 characteristically following the resting spores.

Thallo expanso gelatinoso irregulari; filis primo e centro radiantibus, postea in stratum gelatinosum amorphum laxe consociatis; trichomatibus usque ad 1 mm. longis longioribusve, paulo attenuatis sed non in pilum productis, frequenter pila in filis immaturis; vaginis achromatis, amplis, saccatis, interdum vix lamellosis, divergentibus, raro multo post sporas productis; pseudoramis absentibus vel rarissimis; cellulis basalibus 6–10 μ crassis, diametro 0.5–1-plo longioribus, paulatim ad apicem attenuatis et 4-plo vel plus crescentibus, ad dissepimenta constrictis, contentis laevibus aut paulo granulosis, haud pseudovacuolis, aerugineis; propagatione hormogoniis frequenter; sporis rectis cylindricisque aut basi paulo inflatis, 25–65 μ longis, 8–21 μ crassis, tegumento exteriori laevi, achromato, aut rarius pallide luteo aetate progrediente, solitariis aut rarius 2-seriatim, heterocystis interpositis vel non, interiectis sporis raro; heterocystis terminalibus, fere sphaericis vel sphaerico-depressis, raro ovalibus, diametro 8–12 μ , intercalaribus, fere compressis, heterocystis terminalibus 1 vel pluribus; heterocystis intercalaribus 1 vel pluribus, semper 1, fere 2–3 sporas sequentibus.

Type locality. — Lake La Joya, La Joya, Texas.

Collector. — Dr. E. U. Clover, February 28, 1933.

This species is characterized by the scattered condition of the filaments within a gelatinous stratum, a habit not unknown, but widely different from that ordinarily found within the genus. It shows its essential relationship to the genus, however, through the occurrence of young colonies in spherical groups within the general gelatinous matrix. A more noteworthy characteristic is the constant occurrence in mature filaments of one or more heterocysts separating the resting spore from the first vegetative cell.

The most closely related species is *G. Pilgeri* Schmidle from Brazil, from which *G. heterocysta* is readily distinguishable. The Brazilian species grows in hemispherical masses of microscopic size, containing but few filaments, the ends of which terminate in hairs that extend out beyond the limits of the mass. The individual sheaths are hyaline at first, later becoming yellow-brown and diffuent. The cells of the trichome are about $8\ \mu$ wide, and 1–1.5 times as long, suddenly (?) running out into a short hair. Heterocysts are basal often 2, and intercalary between the resting spores, and often at the site of the uppermost resting cell. Resting spores ellipsoid to rounded, cylindrical, mostly slightly curved, with a smooth firm outer membrane, $12\text{--}16\ \mu$ wide, $29\text{--}70\ \mu$ long, often several in a series but separated by heterocysts.

G. heterocystosa differs from *G. Pilgeri* chiefly in growth habit, in its colorless sheaths and colorless or light yellow spore membranes, in its straight resting spores, which are almost always solitary and which when in series are not necessarily separated by a heterocyst, in the deciduous character of the hairs, and in the complete inclusion of the trichomes within the gelatinous mass.

Oedogonium Cloverae, sp. nov.

(Pl. XVIII, Figs. 2–3)

Diocious, nannandrous; oögonium single, more rarely two together, ellipsoid to subellipsoid, opening by a lid, division supreme or nearly so, $23\text{--}30\ \mu$ long, $19\text{--}22\ \mu$ wide; oöspore conforming to the oögonium or more rarely subglobose, filling the oögonium, $21\text{--}25\ \mu$ long, $18\text{--}21\ \mu$ wide, spore wall very thick, yellow-brown, of three layers, the inner two smooth, the outer layer covered with closely set short spines, the middle layer thick; suffultory cell not inflated; dwarf males on (or, rarely, near) the oögonium, not on the suffultory cell, one- or often 2–3-celled, frequently curved toward the oögonium;

stipe cell 5–6 μ wide, 13–17 μ long; antheridia single or two together, 4–5 μ wide, c. 6 μ long; vegetative cells cylindrical, 3–6 μ wide, c. 16–30 μ or more long, epiphytic on other algae.

Dioicum, nannandrium; oogoniis singulis, rarius 2, ellipsoideis vel subellipsoideis, operculo apertis, circumscissione supremis aut paene supremis, 23–30 μ longis, 19–22 μ crassis; oosporis oogoniis conformantibus et lumen complentibus aut rarius subglobosis, 21–25 μ longis, 18–21 μ latis, membrana crassa triplici, brunneo-lutea, endosporio laevi, mesosporio crasso laevique, episporio echinato; cellulis suffultoriis non tumidis; nannandribus in oogoniis (rarissime ad), nec in cellulis suffultoriis, 1- vel saepe 2–3-cellulis, frequenter curvatis; stipite 5–6 μ crasso, 13–17 μ longo; antheridiis 1–2, 4–5 μ crassis, c. 6 μ longis; cellulis vegetativis cylindricis, 3–6 μ crassis, c. 16–30 μ longis vel longioribus, epiphyticis in aliis algis.

Type locality. — Lake La Joya, Hidalgo Co., Texas.

Collector. — Dr. E. U. Clover, February 28, 1933.

This species lies very close to *Oedogonium longatum* Kütz. and *Oe. rugulosum* Nordst. It differs from both species in the character of its spore wall, in the supreme division, and in the shape of the oogonium. The oogonia and the oöspores are somewhat larger than those of *Oe. longatum*.

The form was collected from a number of different localities in Lake La Joya, and was found on several different hosts.

Oedogonium rufescens var. **fruticosum**, var. nov.

Oögonia usually more than one, commonly 2–5-, up to 9-seriate; vegetative cells nearly capitellate.

Oogonia frequenter non solitaria, plerumque 2–5-seriata vel raro 9-seriata; cellulis vegetativis fere capitellatis.

Type locality. — Brooks Co., near Hidalgo Co. line.

Collector. — Dr. E. U. Clover, April 9, 1933.

Nitella praelonga A. Br.

(Pl. XVII; Pl. XVIII, Figs. 7–9)

Nitella praelonga A. Br., which is said to be the largest known *Nitella*, is a form apparently of extremely rare occurrence. Recorded from the North American continent only, it has been collected but twice before: from the "Santee Canal," South Carolina, by Dr. Ravelin, in 1853; and also from Texas by Lindheimer, in the

summers of 1847 and 1848, "in three creeks between the upper Guadalupe and Pierdenales, often at a depth of ten feet" (Allen, 1894). It was collected in rather large quantities in February, 1933, and again in December, 1934, by Dr. Clover from two localities in Texas, a low marshy area filled by flood waters from the Rio Grande, between San Benito and Brownsville, and most abundantly from barrow pits near Mercedes. It is interesting to note that these two stations are very distant from those in which Lindheimer made his collections. Because of the rarity of the plant and because literature referring to the form is very scarce, it seems advisable to include here a description based upon the present abundant collections.

Plants robust, varying from 10 to 60 cm. high (reported to reach a height of 6 feet or more); lightly incrustated with lime, uncorticated; branchlets straight, 6-12, commonly 9 or 10, in a verticil, sterile branchlets varying from 1.5 to 2 times as long as the internodes to 0.5 times as long or slightly shorter, unfurcated but with a cluster of minute terminal rays at the tips which are very inconspicuous and easily lost; plants monoecious, fertile branchlets as many as 6 in one whorl, shorter than the sterile ones, bearing antheridia and oögonia in compact terminal cones, made up of 2-6, usually 4, fertile whorls, one or two short branchlets in some originating just above the first fertile whorl, so that the cone may appear branched; reproductive structures enclosed in a gelatinous exudation; the cone made up of a compact series of whorls of branchlets arising at right angles to the central axis, normally 8, rarely 7 branchlets in a whorl, each branchlet once divided, the first segment short, giving rise to 3 sterile bracts and a terminal antheridium on a long flask cell, the oögonium arising at the node on the adaxial surface, the sterile bracts tending to enclose the reproductive structures; antheridia produced before the oögonia and maturing early, so that in the basal part of the cone the oögonia appear to be terminal on the branchlet; antheridia 250-375 μ in diameter, 8 shield cells; oögonia 650-775 μ long, 500-600 μ wide, cortical cells with 7-9 convolutions; coronula up to 40 μ high, early deciduous; oöspores 425-510 μ long, 365-500 μ wide, black or very dark brown, bearing 6-7 deep spiral furrows.

The cones bear a striking resemblance to those of *Equisetum* both in external appearance and in the arrangement of the fertile whorls. The incrustation of the plants is of the banded type usually found in this genus. The oögonia correspond exactly in position to

the sterile bracts in relation to the antheridia. Sterile plants may form whorls of bulbils at the nodes instead of branchlets, no branch being formed on the plant, or at least none persisting.

The characteristic features of *N. praelonga* are: (1) the manner of bearing reproductive structures universally on much-reduced and modified branches borne in whorls compacted into cones, (2) the solitary oögonia, (3) the terminal reproductive areas, (4) the non-forking sterile branches, (5) the large number of branchlets in a whorl, and (6) the proportionally long branchlets.

The writer wishes to acknowledge with gratitude the assistance of Dr. Wm. Randolph Taylor, under whose guidance the work has been carried out, and of Dr. Elzada U. Clover and Professor H. H. Bartlett, of the University of Michigan, for aid in the writing of the paper. She is indebted to Dr. L. H. Tiffany of Ohio State University for advice upon the treatment of the new *Oedogonia* and to Dr. G. O. Allen of England for the identification of *Nitella praelonga*.

UNIVERSITY OF MICHIGAN

BIBLIOGRAPHY

- ALLEN, T. F. 1894. The Characeae of North America. Part II, Fasc. II, pp. 9-15.
- BRAUN, A. 1868. Die Characeen Afrikas. Monatsber. der königl. Akad. Wiss., pp. 782-872.
- COLLINS, F. S. 1909-18. The Green Algae of North America. Tufts College Studies. Scientific Series 2: 79-480; Supplementary Paper, 3 (2), 71-109, 1912; Second Supplementary Paper, 4 (7), 1-106, 1918.
- CZURDA, V. 1932. Zygnemales. In A. Pascher, Die Süßwasserflora Deutschlands, Österreichs, und der Schweiz, Heft 9: 1-232.
- GEITLER, L. 1925. Cyanophyceae. In A. Pascher, Die Süßwasserflora Deutschlands, Österreichs, und der Schweiz, Heft 4: 1-250.
- 1930-32. Cyanophyceae. In L. Rabenhorst, Kryptogamen-Flora von Deutschland, Österreich, und der Schweiz, Heft 14: 1-1196.
- GROVES, J., AND BULLOCK-WEBSTER, G. R. 1920-24. The British Charophyta. Vols. I-II. Royal Society, London.
- HEERING, W. 1914. Chlorophyceae 3. In A. Pascher, Die Süßwasserflora Deutschlands, Österreichs, und der Schweiz, Heft 11: 1-250.
- LEMMERMANN, E., BRUNNTHALER, J., AND PASCHER, A. 1915. Chlorophyceae 2. In A. Pascher, Die Süßwasserflora Deutschlands, Österreichs, und der Schweiz, Heft 5: 1-250.

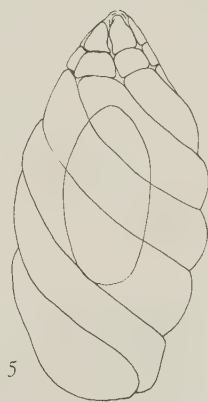
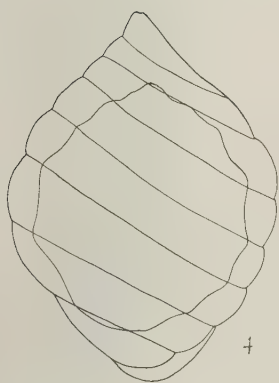
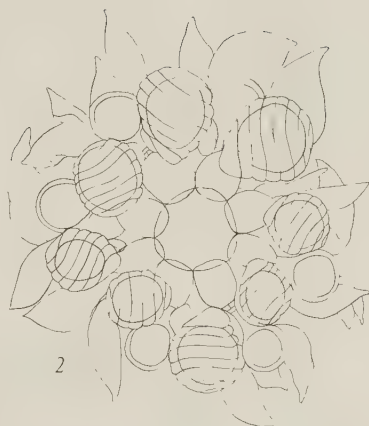
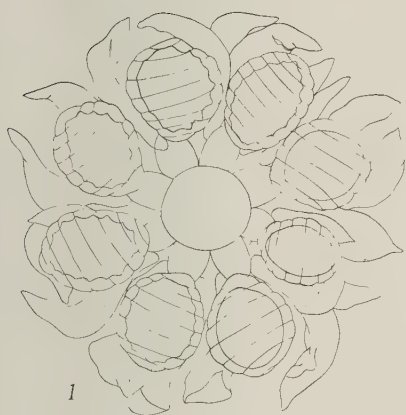
- MIGULA, W. 1900. Die Characcen. *In* L. Rabenhorst, Kryptogamen-Flora von Deutschland, Österreich, und der Schweiz, 2. Auflage, 5. Band, 1-765.
- PASCHER, A. 1927. Volvocales-Phytomonadinae. *In* A. Pascher, Die Süßwasserflora Deutschlands, Österreichs, und der Schweiz. Flagellatae IV — Chlorophyceae I, Heft 4: 1-506.
- AND LEMMERMANN, E. 1913. Flagellatae II. *In* A. Pascher, Die Süßwasserflora Deutschlands, Österreichs, und der Schweiz, Heft 2: 1-192.
- SCHILLER, J., AND MIGULA, W. 1925. Heterokontae, Phaeophyta, Rhodophyta, Charophyta. *In* A. Pascher, Die Süßwasserflora Deutschlands, Österreichs, und der Schweiz, Heft 11: 1-250.
- SMITH, G. M. 1933. Fresh-Water Algae of the United States, 716 pp., 449 figs. New York.
- TIFFANY, L. H. 1930. The Oedogoniaceae, 188 pp., 64 pls. Columbus, Ohio.
- TILDEN, J. E. 1910. Minnesota Algae. Vol. I. Myxophyceae, 328 pp., 20 pls. Minneapolis.

EXPLANATION OF PLATE XVII

Nitella praelonga

- FIG. 1. Section through mature cone, showing position of oögonia, $\times 19$
- FIG. 2. Section through young cone, showing position of antheridia and oögonia, $\times 38$
- FIG. 3. Habit sketch, $\times \frac{3}{8}$
- FIG. 4. Mature oögonium containing oöspore, $\times 52$
- FIG. 5. Young oögonium, showing crown cells, $\times 215$

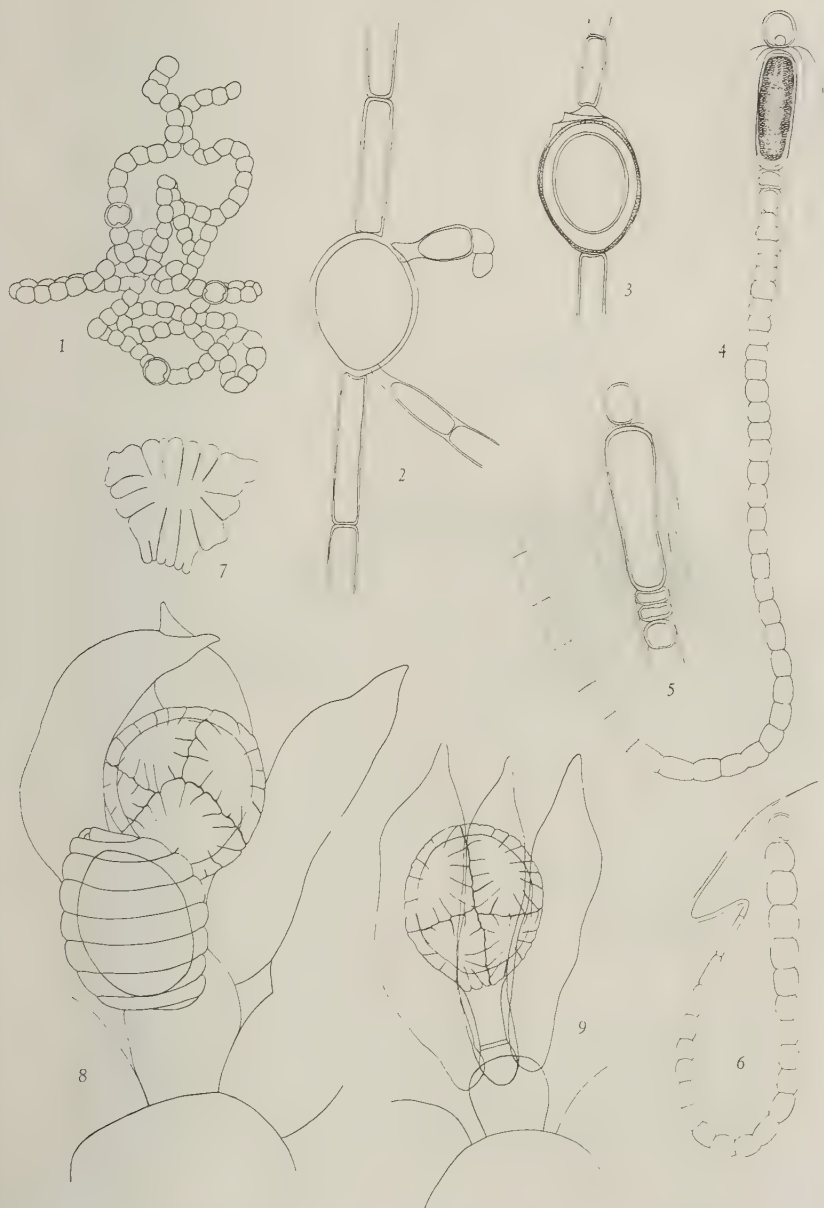
PLATE XVII



EXPLANATION OF PLATE XVIII

- FIG. 1. *Anabaena contorta*, $\times 700$
FIG. 2. *Oedogonium Cloverae*, antheridium and oögonium, $\times 1680$
FIG. 3. *Oedogonium Cloverae*, oöspore, $\times 1560$
FIG. 4. *Gloeotrichia heterocystosa*, $\times 466$
FIG. 5. *Gloeotrichia heterocystosa*, resting spore and heterocysts, $\times 910$
FIG. 6. *Gloeotrichia heterocystosa*, young filament, $\times 470$
FIG. 7. *Nitella praelonga*, antheridial plate, $\times 74$
FIG. 8. *Nitella praelonga*, young fertile branchlet, adaxial view, $\times 68$
FIG. 9. *Nitella praelonga*, young fertile branchlet, abaxial view, $\times 68$

PLATE XVIII



RUSTS FROM THE LOWER RIO GRANDE VALLEY, TEXAS *

EDWIN B. MAINS

THIS paper is based on collections of rusts obtained by Dr. Elizabeth U. Clover in an investigation of the flora of the lower Rio Grande Valley of Texas. Her study was made in five counties, Zapata, Starr, Hidalgo, Cameron, and Wallacy, during three periods: June to September, 1932; February to July, 1933; and November, 1933, to February, 1934.

Although attention was directed mostly to phanerogams, other groups were by no means neglected, and some very interesting collections were obtained, especially in the Uredinales. In this order forty collections distributed among twenty-six species were secured. These have furnished important additional information in regard to the rusts of southern Texas. Twenty of the twenty-six species are mostly tropical in their distribution. It is, therefore, puzzling to find in this predominately tropical flora two species, *Melampsora monticola* and *Puccinia ornata*, which have hitherto been reported from somewhat restricted areas in the north temperate zone. Four species, *Melampsora monticola*, *Uromyces leptodermus*, *Puccinia Lantanae*, and *P. ornata*, are apparently reported for the first time from Texas. *Puccinia incondita* has previously been known only from the type. A microcyclic rust of *Baccharis glutinosa* proves to be an undescribed species. As a result of the study of *Puccinia Cameliae* it is concluded that the species belongs in the genus *Angiopsora*.

LIST OF SPECIES

MELAMPSORA MONTICOLA Mains. — On *Euphorbia (Galarrhoeus) sp.*, Swallow's Club House, Alamo, Hidalgo Co., April 12, 1933 (889); associated with *Uromyces distyosperma*. This rust has hitherto been reported only from the Rocky Mountain region from Wyo-

* Papers from the Department of Botany and the Herbarium of the University of Michigan, No. 569.

ming to the southern part of California. Therefore to find it occurring in a rust flora which is predominately tropical is astonishing. Arthur¹ lists *Tithymalus leptocerus* (Engelm.) Arth., *T. Palmeri* (Engelm.) Abrams, and *T. robustus* (Engelm.) Small as hosts. These species are retained in the genus *Euphorbia* by some authors and are placed in the genus *Galarrhoeus* by others.

PHYSOPELLA FICI (Cast.) Arth. — On *Ficus carica* L., Agricultural Experiment Station, Weslaco, Hidalgo Co., Sept. 10, 1932 (556). A common rust of *Ficus*, specially in tropical regions.

KUEHNEOLA MALVICOLA (Speg.) Arth. — On *Hibiscus cardiophylla* Gray, Rio Grand City, Starr Co., Dec. 1, 1933 (1373a). This rust ranges from southern United States southward into the west Indies and Central and South America.

Angiopsora Cameliae (Mayor), comb. nov. (*Uredo Cameliae* Mayor, *Puccinia Cameliae* Arth.). — On *Setaria macrostachya* H.B.K., west of Raymondville, Wallacy Co., Feb. 10, 1934 (1768). In the United States this rust has been reported only from Texas. It has also been collected in the West Indies and northern South America. As a result of a study of specimens in the Herbarium of the University of Michigan it is concluded that the species belongs in the genus *Angiopsora*. The uredinia are deep-seated and more or less covered by the overarching epidermis and paraphyses. The paraphyses are few and peripheral, thin-walled, hyaline or yellowish, clavate, 6-9 μ broad and 30-40 μ long. The urediniospores are apparently sessile. The teliospores are one-celled, 10-15 $\times$ 16-28 μ , no pedicels are evident, and the spores are catenulate in rows of 1 to 4. They are thin-walled except for the uppermost spores, which are thickened at the apex, 6-10 μ .

UROMYCES DICTYOSPERMA E. & E. — On *Euphorbia* (*Galarrhoeus*) sp., Swallow's Club House, Alamo, Hidalgo Co., April 12, 1933 (889); associated with *Melampsora monticola*. This species ranges from Texas northward and westward. It has been reported from Texas on *Euphorbia arkansana*.

UROMYCES LEPTODERMUS Syd. — On *Panicum purpurascens* Raddi (*P. barbinode* Trin.), Palm Grove, Brownsville, Cameron Co.,

¹ Arthur, Joseph Charles, *Manual of the Rusts in United States and Canada*. Purdue Research Foundation, Lafayette, Indiana. 1934.

Dec. 10, 1933 (1511). This specimen has the uniformly thin-walled teliospores characteristic of *U. leptodermus*. Arthur reports the species from southern Florida. It has also been reported in the West Indies, Mexico, and Central and South America.

PUCCINIA ARECHAVALETAE Speg. — On *Cardiospermum Halicacabum* L., Swallow's Club House, Alamo, Hidalgo Co., April 12, 1933 (891); near Rio Grande River, Havana, Hidalgo Co., May 15, 1933 (1125). A tropical rust which enters the United States in southernmost Florida and Texas.

PUCCINIA BACCHARIDIS D. & H. — On *Baccharis glutinosa* Pers., near Rio Grande River, Alamo, Hidalgo Co., April 15, 1933 (919, 920). This rust has been collected in southwestern United States from Texas to southern California. It ranges south into South America.

PUCCINIA CANALICULATA (Schw.) Lagerh. — On *Cyperus esculentus* L., Palm Grove, Brownsville, Cameron Co., Dec. 10, 1933 (1517). A common rust from Canada southward into South America.

PUCCINIA CENCHRI D. & H. — On *Cenchrus parciflorus* Benth., La Joya, Hidalgo Co., March 6, 1933 (731); Alamo, Hidalgo Co., Dec. 7, 1933 (1479). Arthur reports this rust from Florida, Oklahoma, and Texas; also Central America and the West Indies.

PUCCINIA CRASSIPES B. & C. — On *Ipomoea mexicana* Gray, Palm Grove, Brownsville, Cameron Co., Dec. 10, 1933 (1533). Arthur reports this rust from southeastern United States, West Indies, Mexico, and Central and South America.

PUCCINIA HELIANTHI Schw. — On *Helianthus cucumerifolius* Torr. & Gray, on the banks of the Rio Grand River, Alamo, Hidalgo Co., April 15, 1933 (912). A widely distributed rust.

PUCCINIA HETEROSPORA B. & C. — On *Abutilon parvulum* A. Gray, Edinburg, Hidalgo Co., Dec. 30, 1933 (1589); *Hibiscus cardiophyllus* A. Gray, Rio Grande City, Starr Co., Dec. 1, 1933 (1373b); *Sida physocalyx* A. Gray, Alamo, Hidalgo Co., Dec. 1, 1933 (1495). A common rust on species of the Malvaceae throughout the warmer parts of the world.

PUCCINIA INCONDITA Arth. — On *Solanum triquetrum* Cov., in chaparral, Alamo, Hidalgo Co., April 12, 1933 (884). Apparently previously collected only from the type locality, Austin, Texas.

- PUCCINIA LANTANAE Farl. — On *Goniostachium citrosum* Small, Rio Hondo, Cameron Co., Dec. 12, 1933 (1567). This species has been reported in southern Florida. Arthur also lists it from Bermuda, West Indies, Mexico, and Central and South America.
- PUCCINIA LEVIS (Sacc. & Bizz.) Magn. — On *Panicum fasciculatum* Schwartz, Palm Grove, Brownsville, Cameron Co., April 21, 1933 (957). A common rust of tropical America, extending into the United States in southern Mississippi, Louisiana, and Texas.
- PUCCINIA MELAMPODII D. & H. — On *Parthenium Hysterophorus* L., Alamo, Hidalgo Co., July 16, 1932 (151). Arthur reports this species from western Texas. It is widely distributed in tropical America.
- PUCCINIA ORNATA Arth. & Holw. — On *Rumex mexicanus* Meisn., Palm Grove, Brownsville, Cameron Co., April 21, 1933 (952); *Rumex* sp., Alamo, Hidalgo Co., April 12, 1933 (869). The occurrence of this species in a flora which is predominately tropical is very interesting. Arthur gives the distribution in North America as Maine to Alberta near the international boundary between the United States and Canada. It also occurs in northern and eastern European Russia. The correlated, long-cycled species, *Puccinia Phragmites*, has a much wider distribution. It is possible that short cycling has occurred in several isolated areas.
- PUCCINIA PASPALICOLA (P. Henn.) Arth. — Aecia, on *Solanum* sp. (1784), uredinia on *Paspalum* sp. (1783), Goodwin's Club House, Hidalgo Co., Feb. 13, 1934. A common rust of the tropics.
- PUCCINIA PURPUREA Cooke. — On *Sorghum halapense* (L.) Pers., Alamo, Hidalgo Co., May 20, 1933 (1183); Edinburg, Hidalgo Co., Dec. 31, 1933 (1615). A common rust throughout the southern part of the United States wherever sorghum is grown.
- PUCCINIA RAUNKAERII Ferd. & Winge. — On *Rivina laevis* L., near the Rio Grande, Tabasco, Hidalgo Co., July 25, 1932 (217); Swallow's Club House, Alamo, Hidalgo Co., April 12, 1933 (890). In the United States this rust has been reported only from southern Texas. It also occurs in the West Indies and South America.
- Puccinia riparia**, sp. nov. — Telliis hypophyllis, brunneis, pulvinatis, 0.2 mm. latis, aggregatis; teliosporis oblongis, 12-18 × 30-44 μ , apice rotundatis, medio leniter constrictis, deorsum rotundatis vel leniter attenuatis; membranis flavo-brunneis, 1 μ crassis,

ad apicem 6-10 μ , pedicellis $4 \times 10-30 \mu$. In foliis *Baccharidis glutinosae*, Alamo, Hidalgo Co., April 15, 1933, Elzada U. Clover (1130). Specimen typicum in Herbario Universitatis Michiganensis conservatum.

Telia hypophyllous, brown, pulvinate, 0.2 mm. wide, grouped; teliospores oblong, $12-18 \times 30-44 \mu$, rounded above, slightly constricted at septum, rounded or slightly attenuated below; walls yellowish brown, 1 μ , thickened at apex 6-10 μ ; pedicels $4 \times 10-30 \mu$. On *Baccharis glutinosa*, Alamo, Hidalgo Co., April 15, 1933 (1130). This species differs from the other microcyclic species on *Baccharis* in spore size and length of pedicel.

PUCCINIA RUELLIAE (B. & Br.) Lagerh. — On *Ruellia tuberosa* L., Roma, Starr Co., Dec. 1, 1933 (1385, 1389A); Alamo, Hidalgo Co., Dec. 7, 1933 (1487); Edinburg, Hidalgo Co., Jan. 3, 1934 (1607). A fairly common rust in the southern half of the United States and in tropical America.

PUCCINIA SUBSTRIATA Ellis & Barth. — On *Paspalum Langei* (Tourn.) Nash, near Olmito, Cameron Co., Jan. 16, 1934 (1656); *Setaria glauca* (L.) Beauw., Palm Grove, Brownsville, Cameron Co., April 21, 1933 (961). A common rust of tropical America. Arthur reports it as far north as Nebraska.

PUCCINIA TRIANNULATA (B. & C.) Jacks. — On *Borrchia frutescens* (L.) DC., Clark Island, Boca Chica, Cameron Co., March 30, 1933 (717). This species has been reported from southern United States, Bahama, and the Bermuda Islands.

PUCCINIA XANTHII Schw. — On *Ambrosia sp.*, Penitas, Hidalgo Co., March 15, 1933 (666); *Xanthium speciosum* Kearney, Roma, Starr Co., Sept. 1, 1932 (501). A common rust with wide distribution in North and South America.

FORMATION OF PERIDERM IN THE ENDOSPERM OF *CRINUM ASIATICUM* *

JAMES MERRY

INTRODUCTION

MUCH work has been done on the formation of periderm in plant tissues. In 1889 Douliot (5) described its normal formation in the various tissues of the stem. Kny (6), Appel (1), Massart (7), Olufsen (9), Artschwager (2-3), and Shapavalov and Edson (11) are among those who have worked on the formation in potato. They have shown that it is normally formed on the surface of the tuber and that, if the tuber is wounded, a periderm will be formed on the wounded surface. It has been found that this wound periderm is formed most readily in warm and moist conditions. Weimer and Harter (13) have done similar work on the root of the sweet potato. Rodger (10) examined a formation of periderm as a wound reaction in the submerged leaves of some aquatic dicotyledons. Nakano (8) studied callus formation and wound healing in certain embryos. In this work he included the endosperm of *Ricinus*, in which he showed that the cells on the surface became suberized and that divisions took place in a few of them, but that there was no formation of a periderm layer.

The formation of periderm in endosperm is of interest because it results from the division of cells with a triploid chromosome count, and also because, after the seed matures, the endosperm normally exhibits no further growth, but, rather, decreases in volume as the embryo develops. It is significant in *Crinum* because, in the mature seed, a periderm is normally present in the endosperm as the outer layer of the seed. The usual seed coats and, often, the ovary wall are ruptured by the growth of the endosperm during the maturation of the seed (Coulter and Chamberlain, 4).

* Papers from the Department of Botany of the University of Michigan, No. 564.

METHODS

The endosperm was wounded by cutting slices off the seeds. The wounded seeds and the slices from them were placed in a damp chamber consisting of a covered glass dish that contained damp paper toweling. No attempt at sterilization was made beyond washing the seeds and keeping the dish covered. The dish was kept at room temperature (20° C.).

The tissue was prepared for sectioning by the butyl alcohol method. Various fixing solutions were tried, but Rawlin's and Zenker's seemed to work quite satisfactorily. For staining, light green and crystal violet were used. According to Tison (12), a blue stain with crystal violet in ammoniacal solution is an indication of suberized tissue.

Study was made of the normal tissue and of the wounded tissue at regular intervals after wounding.

DESCRIPTION OF NORMAL TISSUE

The seed of *Crinum* was used because at maturity it is largely endosperm and, since the seed is over an inch in diameter, it makes an excellent source of this tissue. As has been stated, the normal seed coats and, often, the ovary wall are ruptured by the growth of the endosperm during the maturation of the seed. Thus the outer layer of the seed is a thick periderm formed in the endosperm. The surface, which is dry and corky, is light gray. The outer layers of cells are loose, very much collapsed, and heavily suberized. The next five or six layers are also heavily suberized, but have not collapsed so much. Beneath these are four or five layers of suberized cells which are rectangular in cross section and have thinner walls. Beneath these the cells grade off into the larger parenchymatous cells, which make up most of the endosperm (Fig. 6A-B).

WOUND REACTION

Immediately after wounding the cut surface was smooth and damp and white. One day after wounding it had a dried appearance and was a pale yellowish color. Two days after wounding it was more dried in appearance and had a pinkish tinge in places. Three days after wounding it had a corky appearance and was pigmented with various shades of red. The cells on the surface were

slightly suberized, and cells about two layers beneath the surface had begun to divide (Fig. 6C).

Four days after wounding the cut surface appeared more corky and was brownish red. The cells on the surface had begun to collapse and had undergone further suberization. More cells beneath the surface had divided, some of them twice (Fig. 6D).

Five days after wounding the cut surface was still more corky and was reddish brown. The cells on the surface had collapsed further. About two cell layers beneath the surface there was an entire layer of newly formed cells (Fig. 6E). These cells differed from the normal internal cells (Fig. 6B) in that they were rectangular in cross section and resembled those of the normal periderm (Fig. 6A). After having been wounded so long the surface changed externally only in becoming drier and more corky and darker.

Six days after wounding the collapse and the suberization on the surface continued, and more cells had been added to the new layer, which had the appearance of a periderm.

Seven days after wounding almost all the cells outside the periderm layer had collapsed and become suberized. A periderm from two to five cells thick had formed (Fig. 6F). Beyond this point the division became less rapid, taking place mostly in the thinner parts of the periderm layer.

Fifteen days after wounding the outer cells of the periderm had developed thicker walls. The layer was three to five cells thick (Fig. 6G).

Thirty days after wounding the outer cells of the periderm layer were suberized, and the layer was still three to five cells thick (Fig. 6H). No difference in reaction was noted between the wounded seeds which contained embryos and the slices which did not.

DISCUSSION

Nakano, in the only previous work known on the wound reaction of endosperm, found that the wounded surface of the endosperm of *Ricinus* changed to a yellow or a yellow-brown color; that suberization had taken place in the two layers of cells on the wounded surface; and that after about ten days a few cells on the surface had divided one or more times. The change in color and the suberization of the cells on the wounded surface are similar to the reaction in *Crinum*, but, in the latter, division took place beneath the suber-

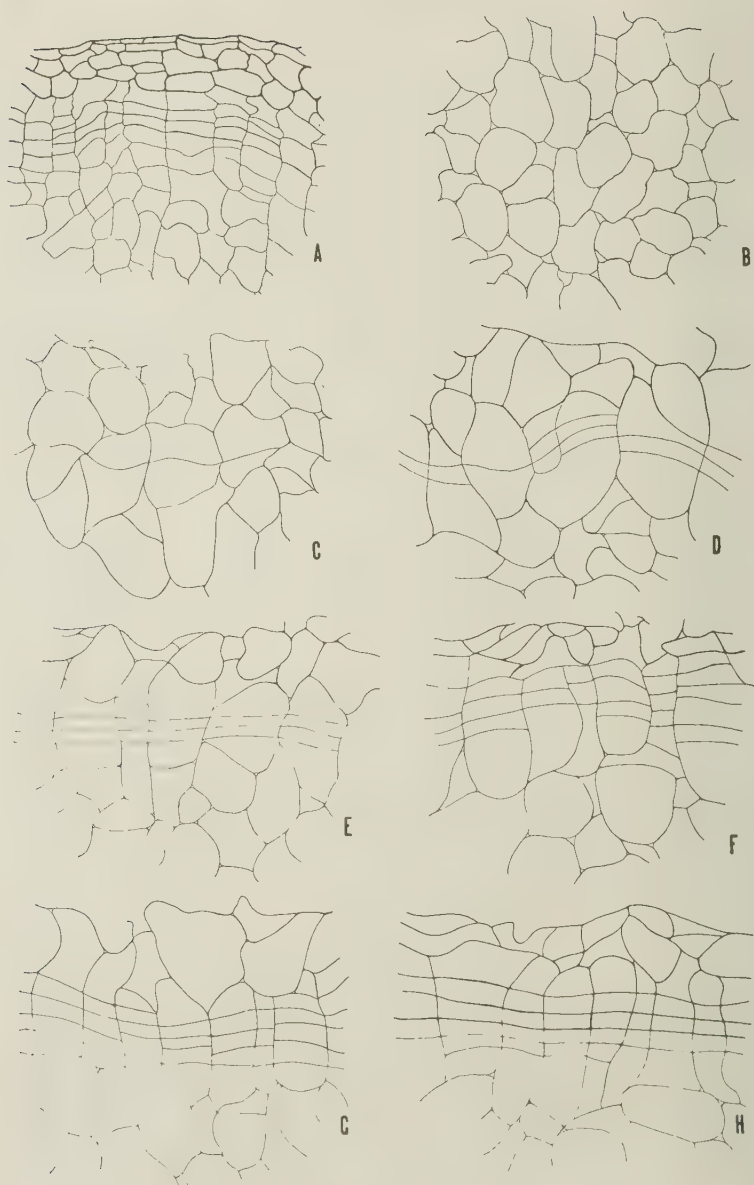


FIG. 6. For explanation of figures see bottom of opposite page.

ized layers, and a periderm layer several cells thick was formed. No other record has been found of a periderm formation in endosperm as a wound reaction.

Nakano was inclined to explain the reaction he obtained by the formation of wound hormone, and the diffusion of a lepto-hormone from the embryo. In *Crinum* the formation of periderm was the same at any distance from the embryo, and pieces of endosperm removed from the seed formed periderm in a manner similar to those containing embryos. Thus it would seem that the effect of phloem hormone can be disregarded. The presence of wound hormone is difficult to prove or to disprove, and further study is necessary.

A more comparable reaction is found in the potato tuber. Art-schwager (3) describes suberization in two or three layers of cells beneath the cut surface and the formation of a periderm three to six cells thick just beneath the suberized region. This is essentially the same as the reaction in the endosperm of *Crinum*.

SUMMARY

The mature seed of *Crinum* is largely endosperm, which normally has an outer layer of collapsed suberized cell beneath which is a periderm layer several cells thick. The interior of the endosperm is made up of large parenchymatous cells.

The wound reaction of the endosperm of *Crinum*, when kept in a damp chamber, is as follows:

1. The wounded surface becomes dry after one day;
2. The wounded surface changes from a white to a red color in two or three days;
3. The cells on the surface begin to collapse and become suberized after three days;
4. A layer of periderm is formed about two cell layers beneath the surface, beginning after three days and reaching its fullest ex-

EXPLANATION OF FIGURE 6

A. Normal periderm on surface of mature seed

B. Normal internal tissue of endosperm of mature seed

C-H. Wounded surface of endosperm 3, 4, 5, 7, 15, and 30 days, respectively, after wounding

tent (three to five cells thick) at the end of seven days, after which the walls of the cells become thickened and suberized.

The cause of this formation is not known, but it is quite certain that the embryo has no effect. It is a new reaction for endosperm, but similar to that of potato and other tissues.

UNIVERSITY OF MICHIGAN

BIBLIOGRAPHY

1. APPEL, O. 1906. Zur Kenntniss des Wundverschlusses bei den Kartoffeln: Ber. deut. bot. Gesell., 24: 118-122.
2. ARTSCHWAGER, E. 1924. Studies on Potato Tuber. Journ. Agric. Res., 27: 809-836.
3. ——— 1927. Wound Periderm Formation in the Potato as Affected by Temperature and Humidity. *Ibid.*, 35: 995-1000.
4. COULTER, J. M., AND CHAMBERLAIN, C. S. 1903. Morphology of the Angiosperms. vii + 348. D. Appleton and Co., New York.
5. DOULIOT, H. 1889. Recherches sur le periderm. Ann. sci. nat. bot., Sér. 7, 10: 325-395.
6. KNY, L. 1889. Über die Bildung des Wundperiderms an Knollen in ihrer Abhängigkeit von äusseren Einflüssen. Ber. deut. bot. Gesell., 7: 154-168.
7. MASSART, J. 1898. La Cicatrisation chez les végétaux. Mém. couronnés Acad. roy. sci., lettres, beaux-arts belgique, 57: 2-68.
8. NAKANO, H. 1924. Untersuchungen über Kallus Bildung und Wundheilungen bei Keimpflanzen. Ber. deut. bot. Gesell., 42: 261-272.
9. OLUFSEN, L. 1903. Untersuchungen über Wundperiderm Bildung an Kartoffelknollen. Bot. Centralbl., Beih. 15: 269-308.
10. RODGER, E. 1933. Wound Healing in Submerged Plants. Am. Mid. Nat., 14: 704-713.
11. SHAPAVALOV, M., AND EDSON, H. A. 1919. Wound Cork Formation in Relation to Seed Piece Decay. Phytopathology, 9: 483-496.
12. TISON, A. 1899. Méthode nouvelle de coloration des tissus subereux. Assoc. franc. Advanc. Sci. Compt. Rend., 28: 454-456.
13. WEIMER, J. L., AND HARTER, L. L. 1921. Wound Cork Formation in Sweet Potato. Journ. Agric. Res., 21: 637-647.

A STUDY OF THE WATER MOLDS OF THE LYDELL STATE FISH HATCHERY AT COMSTOCK PARK, MICHIGAN *

EDWIN Y. MONSMA

INTRODUCTION

IT IS a matter of common knowledge among mycologists and ichthyologists that certain water molds are prevalent in fish hatcheries. Fish and their eggs are often attacked by such molds, which effect the destruction of countless numbers. It is usually assumed that at least one species of Saprolegnia, *S. parasitica* Coker, is parasitic on fish and their eggs. Miss Kanouse (10) has given some valuable information on this subject in her paper on *S. parasitica*, published in 1932.

Coker (4), in his monograph on the Saprolegniaceae, likewise refers to *S. parasitica* as being associated with young fish and their eggs, especially in hatcheries, but he also reports the collecting of several other species from hatchery ponds.

Two hundred and fifty-two samples of water were collected from 15 different sources, chiefly from western Michigan, during the summer of 1934. Eighteen others were taken from ponds of the Lydell State Fish Hatchery. Of those from western Michigan 12.3 per cent produced water molds on hemp seeds; of those from the ponds 55.5 per cent yielded molds. This great difference could not escape attention, especially since it was evident that the molds from the hatchery were not all *S. parasitica*. In a conversation with Mr. Claude Lydell, manager of the hatchery, the writer was informed that these troublesome fungi had increased considerably in the last few years, and that great losses were being suffered each year, presumably because of them.

It was evident that a thorough study of the water molds of the

* A condensed form of a thesis prepared in partial fulfillment of the requirements for the degree of Doctor of Philosophy, Michigan State College.

hatchery with reference to kinds of molds, their distribution, the sources of water supply, and soil contamination not only would be interesting and instructive, but might eventually lead to some method of control.

The writer is indebted to Dr. E. A. Bessey, of Michigan State College, under whose direction this work was undertaken, for helpful advice and encouragement; and to Dr. Ralph Stob, president of Calvin College, who showed a spirit of helpfulness in providing laboratory facilities.

DESCRIPTION OF THE HATCHERY

The Lydell State Fish Hatchery is in Comstock Park, two miles north of Grand Rapids, on Highway 484. The grounds cover an area of about 32 acres, on which 26 ponds of various sizes have been constructed. All but one have soil bottoms. Mill Creek, which supplies most of the ponds with water, winds through the grounds. The hatchery proper receives its water from a tributary of Mill Creek, Strawberry Creek, which runs into Mill Creek about three quarters of a mile north. Three dams have been built, one in Strawberry Creek near its mouth, the other two in Mill Creek. From a point above each dam the water is piped to the various ponds which are connected in series, so that the water runs from one into another and then back into Mill Creek. Each pond has a drainage pipe which, when open, carries the water directly to Mill Creek.

METHODS AND TECHNIQUE

In order to study the water-mold contamination of the hatchery to the best advantage it was deemed advisable to make collections of both water and soil and to divide them into the following main groups: (1) water from the sources; (2) water from the ponds; (3) soil from the bottom of the ponds; (4) soil from the hatchery grounds near the ponds.

The water from the sources was collected from four locations, as follows: (1) Strawberry Creek, just above the dam; (2) Mill Creek, above the point where Strawberry Creek joins it; (3) Mill Creek, above the first dam; (4) Mill Creek, above the second dam. Ten collections were made from each location, a total of 40.

Five collections of water were made from each of the 26 ponds, a total of 130.

The soil collections from the bottoms had to be taken when the ponds were drained. Since the water is let out for only a short time the number was necessarily limited to 4 each from 12 ponds, 48 in all. For the sake of comparison, 48 soil collections were obtained from the hatchery grounds near each of the 12 ponds from which the bottom soil came.

A belt with 18 screw-top vials of 20 c.c. capacity was used. The entire sterile vial was submerged and the top removed and replaced below the surface of the water, eliminating the possibility of contamination with mold spores from other sources. Soil collections were made in similar vials. The surface soil was removed and a soil boring was made with the sterile vial.

To determine the contamination of the deeper water in the sources, hawthorn fruits were suspended in the water in ordinary soap shakers. The fruits were left in the water from one to two weeks and then examined for molds.

In the laboratory both soil and water samples were transferred to sterile Soyka dishes. Sterile distilled water was added to the soil, and the contents were mixed by agitation. Then two hemp seeds and a house fly, sterilized in a pressure cooker under 15 lb. pressure, were dropped into each dish. If mold spores were present, the hyphae usually appeared on the seeds or the fly within one week.

To get these molds into pure culture, single-hypha tips were transferred to potato dextrose agar plates. In most cases the characteristics needed for their classification were obtained from these single-hypha cultures. A few single-spore cultures were made to determine characteristics more accurately. The technique used to isolate single spores may be considered a modified form of the method described by Kauffman (11). It may be summarized as follows: Clip off a quantity of mycelium producing zoöspores; mount this in sterile water on a slide; stir it and then remove all hyphae and hyphal segments, so that only zoöspores remain in the water; invert the slide and place it with the drop downward on agar in a petri dish; leave it this way overnight. The next morning germinating zoöspores may be transferred, with bits of agar, to other plates. It was found that, if the initial culture is relatively free from bacteria and if sterile instruments are used, this process can be employed without danger of contamination with more ease and in less time than any other method that was tried. In studying details of the

developmental processes the use of moist chamber cultures, constructed as suggested by Giltner (6), was of great aid.

RELATIVE ABUNDANCE OF WATER MOLDS IN SOURCES, PONDS, AND SOIL

The number of molds produced in specimens brought to the laboratory and the percentage of water-mold contamination of the sources, ponds, and soil, as indicated by them, are as follows: 28, or 70 per cent, of 40 specimens collected from the sources; 71, about 55 per cent, of 130 specimens from the ponds; 19, about 40 per cent, of 48 soil samples from the bottom of the ponds. Examination of these data indicates a uniform gradation of contamination from the water of the sources to the water in the ponds, and again from the water in the ponds to the soil from the bottom of the ponds. In the first the contamination is 15 per cent higher than in the second; in the second, 15 per cent higher than in the third. The high contamination of the water from sources is no doubt responsible for the lower, but nevertheless serious, contamination of the water and the soil from the ponds.

CLASSIFICATION AND DESCRIPTION OF ISOLATED MOLDS

As stated in the section on methods and technique, an attempt was made to get into single-hypha-tip or single-spore cultures the 120 forms produced in the various samples of water and soil. Ninety-four were successfully isolated. The characteristics necessary for the classification of all but 8 were obtained by culturing them on hemp seed, a house fly, and a dermestid larva. Three were definitely *Saprolegnia*, 3 were *Achlya*, but the characteristics for species determination were lacking. The remaining 80 were referred to species with keys given by Coker (4) and by Humphrey (8).

The species isolated and their frequency of occurrence are as follows: *Saprolegnia parasitica*, 34; *S. ferax*, 17; *S. diclina*, 4; *S. hypogyna*, 4; *S. anisospora*, 2; *S. asterophora*, 1; *S. delica*, 1; *S. mixta*, 1; *Achlya oblongata* var. *globosa*, 4; *A. Klebsiana*, 3; *A. racemosa*, 3; *A. americana*, 1; *A. hypogyna*, 1; *Achlya* sp. (sterile), 4.

Saprolegnia parasitica Coker

Saprolegnia parasitica was collected from all sources except Strawberry Creek and from all but 9 of the 26 ponds. It was found,

in soil as well as in water, quite consistently from September to January.

Kanouse (10), in 1932, definitely noted for the first time the appearance of oögonia in this species and described the structure. They were produced in 10 of the 34 cultures listed above. Invariably, however, only a few of them were found in any one culture. Their structure agreed on the whole with that described and illustrated by Kanouse. They had diclinous antheridia; their walls were thin, smooth, and unpitted. They measured 40-114 μ , mostly 60-80 μ . Kanouse gives their size as 65-135 $\times$ 60-75 μ (65-95 μ). The oöspores were dark and subcentric, 19-24 μ , and a few large ones 28-30 μ in diameter as compared with Kanouse's 18-22 μ . Notwithstanding these differences the molds are no doubt *S. parasitica*, since the rest of our observations agree perfectly with the descriptions by Kanouse.

In his key to the species of *Saprolegnia* Coker (4) remarks that *S. parasitica* probably belongs to the *ferax* group. However, since the oögone walls are thin, and pits, if present, are not conspicuous, and since the antheridia, at least in the main, are diclinous, it would naturally fall in the *diclina* group.

The abundance of *S. parasitica* at the hatchery may be indicated by the following summary of the identified forms: 8, about 47 per cent, of the 17 forms from water at the sources; 20, about 43 per cent, of the 46 forms from water from the ponds; 6, about 40 per cent, of the 16 forms from soil at bottoms of ponds; an average of 43.3 per cent.

Saprolegnia ferax (Gruith) Thuret

A large number of oögonia and a relatively small number of gemmae were evident in nearly all cultures. With a few exceptions the measurements of the diameters of oögonia and oöspores fell within the extremes given for *S. ferax* by Coker.

Saprolegnia diclina Humphrey

Four cultures agreed entirely with the descriptions of *S. diclina*. There can be no doubt as to their identity.

Saprolegnia hypogyna Pringsheim

From Coker's description of *S. hypogyna* it is evident that it has great variation in form. Pringsheim (15) first described it as a

variety of *S. ferax*. It was recognized as a species by De Bary (2). Maurizio (12) lists at least 5 varieties. In America it has heretofore been found only by Kauffman, in Michigan.

The writer has compared the forms listed above with the original illustrations and descriptions by Pringsheim and De Bary and feels certain that they belong to this species. Whether they are the same variety as the one which Kauffman found has not been determined.

Saprolegnia anisospora De Bary

Considerable difficulty was experienced in placing *S. anisospora*. The *Durchwachsung* of the zoösporangia clearly showed this form to be a species of *Saprolegnia*. The oöspores, however, were eccentric, which is not characteristic of this genus. Single-spore cultures were made, and a tuft of mycelium that originated from a single spore and grew on a dermestid larva was mounted in a hanging drop. The fungus continued to grow for 48 hours, and observation soon showed that at least two sizes of zoöspores were discharged from different zoösporangia, a characteristic found in *S. anisospora*. On the following day oögonia were starting to form. They bore diclinous antheridia. Oöspores were present the next day; they were centric. Measurements of hyphae, zoöspores, oöspores, antheridia, and zoösporangia agreed with those given by Coker, with the exception that the encysted zoöspores varied from 12.25 to 17.5 μ . The smaller ones were few; most of the spores were either 14 or 17.5 μ . A single sporangium gave rise to either the larger or the smaller form. The swimming spores, however, were about 12 μ in their smallest diameter, which is nearer to the measurements given by Coker (4), who states: "... the smallest spores are about 8-9 μ in diameter, others from 10.5-11.5 μ , the large ones from 13.7-14.8 μ ." The oöspores observed in the original culture, which were apparently eccentric, were similar to those illustrated by De Bary (3), who gives no measurements. They are no doubt abnormal, and our observations substantiate Coker's suggestion: "... one is inclined to suspect that De Bary, who rarely made a mistake, was in this case wrong in thinking the normal eggs eccentric. His figures clearly show eccentric eggs, but may they not have been breaking down? This seems the more likely as no other *Saprolegnia* has an eccentric egg."

Saprolegnia asterophora De Bary (1)

S. asterophora is characterized by proliferation of new hyphae through old zoösporangia and oögonia with papillae, having one, seldom two, oöspores.

Saprolegnia delica Coker

S. delica is identified by oögonia with thin walls having inconspicuous pits and delicate antheridia, which are for the most part diclinous.

Saprolegnia mixta De Bary

S. mixta is much like *S. ferax*, listed above, except that it has many oögonia with antheridia. Coker calls attention to the similarity between the two.

Achlya oblongata var. *globosa* Humphrey

The identity of *A. oblongata* cannot be mistaken. Since the oögonia were nearly all spherical and the oöspores averaged more than ten to an oögonium, these collections are, no doubt, of the variety *globosa*, a variety established by Humphrey (8) on the basis of these very characteristics.

When this variety was first encountered, the thick and long hyphae were very conspicuous on hemp seed. They were exceptionally broad at the base and tapered to a point at the top. One was found to be $271.25\ \mu$ in diameter at the base. When the hemp seed was held out of the water the hyphae stood out, perpendicular to the surface of the seed.

Achlya racemosa Hildebrand

The cultures of *A. racemosa* were readily distinguished because of numerous oögonia on short, racemose stalks and because of short, unbranched antheridia arising from the oögonial stalk directly below the oögonium, as described by Hildebrand (7). They had 1 to 3, sometimes 4, seldom 5, oöspores in oögonia measuring $26.25\text{--}50.75\ \mu$. These figures are smaller than those given by Hildebrand (7), Humphrey (8), and Coker (4). The difference may be due to a nutritive factor. Pieters (13) shows that the number of oöspores in an oögonium varies according to the percentage of peptone in the medium.

Achlya Klebsiana Pieters

The cultures of *A. Klebsiana* produced larger oögonia, 63–100 μ , and more oöspores, 3–15, in each oögonium than did those described by Pieters (14) and Coker (4).

Achlya americana Humphrey

A. americana has not hitherto been reported from Michigan.

Achlya hypogyna Coker and Pemberton

A. hypogyna has oögonia of various shapes, many with papillae. Except for the number of oöspores per oögonium, which is greater than that given by Coker, this form agrees with his descriptions and illustrations.

Achlya sp.

In his monograph on the Saprolegniaceae Coker (4) describes and illustrates an *Achlya* species which remained sexually sterile for several months and in which the formation of oögonia could not be induced by means of culture media of various compositions. Our cultures grew from three to four months, without producing sexual organs, under conditions in which other *Achlya* produced abundant oögonia. This is most probably the same *Achlya* species as the one referred to by Coker.

In considering the distribution of any particular species we find that no species confines itself to sources, ponds, or soil. The most representative species are found in all situations. Those that were encountered four times are likely to come from two locations. Seldom is a species found more than once or twice at a particular location. This general distribution indicates a close connection between the contamination of water in the sources, of water in the ponds, and of soil at the bottom of the ponds.

EXPERIMENTS TO DETERMINE THE EXTENT OF PARASITISM
OF WATER MOLDS

Because of the abundance of various species of mold at the hatchery the problem of parasitism with reference to fish and their eggs becomes important. Kanouse (10) has considered it with reference to *S. parasitica* Coker. She concludes (p. 449) that the in-

fection of living eggs and fry by means of zoöspores is not likely, but "that the pressure of growing hyphae on the egg membranes when the eggs are held tightly together is sufficient to allow penetration of the mycelium into the living eggs."

Upon the basis of the numerous infections of living fish in British rivers Huxley (9) more or less assumed the parasitism of a form of fungus, which no doubt was *S. parasitica* Coker.

It was deemed advisable, in connection with this problem, to determine more definitely the extent of the probable parasitism of *S. parasitica* and other species found in collections from the hatchery. Accordingly, the following experiments were undertaken:

1. Experiment with wall-eyed pike eggs

Living eggs of the wall-eyed pike, *Stizostedion vitreum*, were obtained from a shipment received at the hatchery on April 20, 1935. Four apparently living eggs were placed in each of sixty-three vials which contained 10 c.c. of sterile distilled water. Dermestid larvae, supporting growths of *S. parasitica*, were inserted into seven vials.

Others were similarly inoculated with *S. ferax*, *S. diclina*, *S. anisospora*, *A. oblongata* var. *globosa*, and *Achlya* sp., seven of each form, a total of forty-two. To determine whether the mycelia in the vials were actually producing zoöspores, sterile dermestid larvae were placed in each one. They floated on top of the water and were not in contact with the mycelia growing on the other larvae. Any subsequent infection of these sterile larvae must, therefore, have been due to zoöspores set free by the introduced mycelia. The molds used were thus shown to be producing zoöspores in the water which contained the eggs. Many of the eggs adhered to the sides of the vials and, with a few exceptions, none were in contact with the mycelium at the outset of the experiment. Twenty-one vials were not inoculated and were used as controls. This was deemed necessary since the eggs could not be sterilized and a check was needed to determine the likelihood of previous infections. The vials were placed in an icebox, where the temperature ranged from 10 to 15 degrees, mostly 12 to 13 degrees.

The first careful examination was made about forty-eight hours later; thereafter observations were recorded daily. The first showed that about 60 per cent of the eggs in the cultures and about 50 per cent of those in the controls were dead. The high mortality must

be regarded as due to factors involved in the sudden changes to which the eggs were subjected. It is also possible that many were not fertilized and, consequently, died. It cannot be ascribed to fungous infections, since the mortality in the controls was nearly as high as that in the cultures. We conclude that only eggs with great vitality survived the sudden changes. These, therefore, were fit subjects for this experiment.

All the species infected dead fish eggs more or less readily; *S. parasitica* appears to infect them most easily. In no case was a living egg lying out of contact with the mycelium infected. It seems, therefore, that none of these molds are parasitic on fish eggs, so far as infections by zoöspores are concerned.

A few living eggs were observed lying in contact with growing mycelium. They were studied with the aid of dissecting and compound microscopes. The hyphae had enwrapped the eggs so that they could not easily be dislodged and had attached themselves so firmly to the membranes that it was hard to remove them. This phenomenon was not due to pressure, since each egg had been lying by itself. Rather, it seemed to be due to a positive tropism in the nature of thigmotropism. The hyphae did not penetrate beyond the membranes, as they did in the infected dead eggs. The mycelium was removed, so far as this was possible without injuring the eggs. Five of them were then isolated, put in moist chambers, and kept in the icebox. Three were surrounded by *S. parasitica*, one by *S. diclina*, and another by *A. oblongata* var. *globosa*.

Five days later the egg surrounded by *A. oblongata* var. *globosa* was still alive and developing; it contained a living and active embryo. The hyphae showed no further development.

Three days after isolation the egg surrounded by *S. diclina* was still alive. It contained a living embryo and showed no infection.

Of the three eggs surrounded by *S. parasitica* one was dead and severely infected the following day with a tuft of new hyphae extending from the focus of infection. The other two were still alive, but each showed a distinct focus of infection. They were dissected and examined under the compound microscope. At the foci small rhizoid-like hyphae were clumped together on the surface, and also extended into the egg. In these clumps there were several germinating zoöspores, but there was no penetration by the germ tubes.

These observations lead to the conclusion that *S. parasitica* is

parasitic on fish eggs. This parasitism is not merely incidental or passive, or due to some external force such as pressure, but is active. It is limited, however, to the extent that living eggs do not appear to be readily infected by single zoöspores, but, owing to the abundant growth of the hyphae on its surface, the resistance of the egg is broken down and an avenue of entrance for hyphae and perhaps also for germ tubes is established.

For a five-week period the eggs in the controls showed no mold infection. Between the second and the seventh days the mortality rate was about 7 per cent; in the cultures it was 80 per cent. On the basis of these observations it may safely be concluded that the eggs used for this experiment had not previously been infected. The greater rate of mortality in the cultures may have been due to the fact that they contained actively growing mycelium which diminished the relative amount of free oxygen in the water. This conclusion is substantiated by the results obtained for one of the vials that contained an exceptionally weak growth of *S. diclina*. All the eggs in it remained alive although the infection of the test larva on the surface showed that there were zoöspores in the water.

2. Experiments with eggs of black bass

Eggs of the small-mouthed black bass, *Micropterus dolomieu*, were taken from a nest in Pond 2. From the material brought into the laboratory 250 eggs were picked one by one. They were alive and were apparently free from mold contamination. Twenty-five were placed in each of ten petri dishes containing water from Strawberry Creek, which had previously been sterilized, cooled, and aerated by agitation. The eggs were spaced so that no two were in contact and the dishes were inoculated with various mold species. Any infection that might occur would necessarily be due to zoöspores set free in the water or to those that originally clung to the sticky surface of the egg membrane. The cultures were watched to determine whether mold zoöspores would infect living eggs. After two days several were infected; five of them, which contained embryos that were definitely alive, were microscopically examined. The hyphae had not penetrated beyond the membranes, which could readily be removed with fine needles. The embryo was thus set free, apparently alive and not infected.

Several of the dead and infected eggs were examined. Their

membranes could not be removed because of the penetration of hyphae into the embryo.

Fifty-three living and apparently noninfected eggs of the large-mouthed black bass, *Micropterus salmoides*, were put into four petri dishes, as in the preceding experiment. Twenty-four hours later 17 of them were dead and infected, 34 were living and not infected, and 2 were alive and infected. The membranes of the 2 were removed and the embryos found to be without infection. One was in an advanced stage of development; the larva was fully formed, its heart was beating, and the blood could be seen circulating through the vessels.

3. Experiment with eggs of the bluegill

Whether one or more species of water molds are capable of infecting living fish eggs was not determined in the experiments, but an attempt to do so was made with eggs of the bluegill, *Lepomis pallidus*. They were taken from a bed of fine gravel and shells in Lake 2 of Morgan's chain on June 12, 1935. None showed infection. Four hundred were separated out, cleaned, washed in several changes of sterile water and then isolated, twenty-five in a petri dish, with sterilized water from Strawberry Creek. Two dishes were inoculated with zoospores of each *S. parasitica*, *S. ferax*, *S. diclina*, *S. anisospora*, *Achlya oblongata* var. *globosa*, *A. americana*, and *A. Klebsiana*. Two dishes were not inoculated and were used as controls. Sterile hemp seeds were dropped into each to test for the presence of zoospores. Although they had been thoroughly washed and appeared to be entirely free from molds, it was soon evident from the infection of controls that the experimental eggs were not free from contamination. The results are tabulated in Table I.

The table does not record whether the infected eggs were dead or alive. Since bluegill eggs are small that is difficult to determine, even with the use of transmitted light. There is reasonable certainty that all or nearly all the eggs found infected one day after the start of the experiment were living, since several of the membranes were removed and living embryos were found inside. One of the fourteen infected, presumably by *S. parasitica*, hatched a few hours later. In the others the growth of the mold increased and the embryo was killed.

Since, after one day, the controls were only lightly infected, it is evident that the heavy infections found in the dishes inoculated

with *S. parasitica*, *S. ferax*, and *S. diclina* were due to the zoöspores of these species. In each the test hemp seed was infected, and the eggs were surrounded by active zoöspores.

This experiment leads to the conclusion that the outer membranes of living fish eggs are readily infected by zoöspores of certain water-mold species, including *S. parasitica* and *S. ferax*, which are

TABLE I

AMOUNT OF INFECTION FOR BLUEGILL EGGS EXPOSED TO ZOÖSPORES OF VARIOUS WATER MOLDS

Molds	Number of infected eggs after start of experiment			Four days after start of experiment			Total
				Number of eggs			
	1 day	2 days	3 days	Infected	Not infected and hatched	Dead, not infected	
S. parasitica..	14	19	20	22	26	2	50
S. ferax.....	20	22	23	23	25	2	50
S. diclina.....	11	18	20	20	22	8	50
S. anisospora .	0	13	17	17	30	3	50
A. oblongata							
var. globosa.	1	6	11	11	31	8	50
A. americana .	1	12	18	18	29	3	50
A. Klebsiana..	3	14	19	24	26	0	50
Control.....	1	2	12	13	27	10	50

found in large numbers in the water and the soil of the hatchery. As a result, the egg dies, unless the embryo is in an advanced stage of development, in which case the egg will hatch and the larva will be unharmed.

4. Experiment with bluegill fry

To obtain an answer to the question, "Are living fish fry susceptible to water-mold infections?" the very young bluegill fry produced in the preceding experiment were used. While in the petri dishes none of the living fry became infected, though they were surrounded by zoöspores. For better observation they were transferred to vials supplied with fresh, sterile water from Strawberry Creek and were inoculated with zoöspores of *S. parasitica*, *S. ferax*, *S. diclina*, *S. anisospora*, *Achlya oblongata* var. *globosa*, *A. americana*, and *A. Klebsiana*.

Most of the fry used in this experiment lived for a week or more. Of the 153 exposed none were infected while alive, and only 11 were found to be infected when dead. The dead fry were removed at each observation. Since a majority of them were without infection it may be assumed that the few that were found to be infected died from reasons other than mold infection. This experiment, therefore, leads to the conclusion that water molds are not parasitic on fish fry.

5. Experiment with small-mouthed bass fry

One hundred fry of the small-mouthed bass were put into each of 11 battery jars at the hatchery in an effort to determine the parasitism of water molds on fish fry. Zoospore-producing *S. parasitica*, *S. ferax*, *S. diclina*, *S. anisospora*, *A. oblongata* var. *globosa*, *A. americana*, *A. Klebsiana*, and *A. racemosa* were placed at the bottom of eight. These molds were growing on hemp seeds, dermestid larvae, and pieces of boiled fish. Two small dead fish, picked from the hatchery tanks and badly infected with mold, were put in the ninth jar; two were left as controls. Water, which came directly from Strawberry Creek, was kept running through the jars, as is customary when eggs are being hatched. The fry were, therefore, under conditions similar to those that obtained when they were hatched. Daily observations were made for seven days.

The first day all the fry were alive. About 10 per cent of them, however, were covered with yellowish spots, which were thought to be possible foci of mold infection. Twenty-four hours later the number of fry having such spots had increased. Upon microscopic examination they proved to be cysts of a protozoan parasite, *Ichthyophthirius multifiliis*, an infusorium rather abundant at fish hatcheries and causing a disease known as "ich." No mold growth was observed, although it was looked for especially at the points of protozoan infection, and there was no dying off of fry until the fifth day. Dead specimens were removed and microscopically examined each day; living ones, at the end of the experiment. Of the 925 examined, 108 were living and not infected; 817 were dead, of which 411 were infected and 406 not. That the living fry were exposed to mold zoospores is shown by the fact that infected dead specimens were found in all the eleven jars.

This experiment does not serve to show parasitism for any particular species of mold, because the controls also contained zoospores,

but since no living specimens with infection were seen in any jars, we may conclude that none of the mold species used are parasitic on fry of the small-mouthed bass. This conclusion is similar to that already reached for the bluegill fry.

6. Experiment with Lake Michigan shiners

To determine the effects of water molds on older fish an experiment with Lake Michigan shiners was undertaken. A battery of 11 jars was set up, as was done in the case of the small-mouthed bass fry. In each, 6 shiners were placed, 3 of which were injured on the side by means of a scalpel. Daily observations were carried on for two weeks. Dead fish were removed and examined as soon as they were found. At the close of the period 26 had died from the effects of molds; 34, from other causes; 6 were still alive and showed no mold infection.

Of the living fish one was an injured specimen taken from the jar supplied with *S. ferax*. The other 5 had not been injured; 3 were from the jar containing *A. oblongata* var. *globosa*; 1 was from the jar with *A. Klebsiana*; 1, from the jar with the infected fish.

Of the 34 that died uninfected, 5 escaped from the top of the aquarium and were found on the floor; 29 evidently could not adjust themselves to the confines of the aquarium, although many of them lived for nearly two weeks.

Special importance is attached to the 26 that died from mold infections. The infection could nearly always be seen on the fish a day or two before death. Once the growth got started its spread was very rapid. Not one fish lived more than two days after the infection was noticed. In 16 of the 26 it started at the point of injury on the side; in the others, which had not been injured intentionally, either at the tail or in the gills and head region. This is significant, since it is well known that fish are easily injured during handling and transportation, especially at the anterior and posterior ends. Therefore it is likely that the infection started at a point of injury on each fish. Under the microscope it was in every case found to be superficial. It established itself at the point of injury and from there spread as a thick mat of mycelium over the rest of the body, without penetrating deeply into the tissues.

Dead and infected fish were found in all jars used, controls as well as others. The experiment, therefore, does not show that any

particular species of mold is the offender. If, however, we consider the mortality rate due to water mold, it does indicate that *S. parasitica* may be the chief if not the only offender. For this reason the information that has bearing on this point is given.

TABLE II
MORTALITY RATE OF THE FISH THAT DIED FROM MOLD INFECTIONS

Molds	No. of specimens dying from mold	Day on which death occurred	Rate of mortality per day
<i>S. parasitica</i>	4	3rd	$1\frac{1}{3}$
<i>S. ferax</i>	1	3rd	$\frac{1}{3}$
<i>S. diclina</i>	3	7th	$\frac{3}{7}$
<i>S. anisospora</i>	3	3rd	1
<i>A. oblongata</i> var. <i>globosa</i>	2	10th	$\frac{1}{5}$
<i>A. americana</i>	1	3rd	$\frac{1}{3}$
<i>A. Klebsiana</i>	3	6th	$\frac{3}{6}$
<i>A. racemosa</i>	1	8th	$\frac{1}{8}$
Infected fish.....	1	6th	$\frac{1}{6}$
Control No. 1....	3	9th	$\frac{1}{3}$
Control No. 2....	4	12th	$\frac{4}{12}$
Total.....	26		

S. anisospora, although it showed a mortality rate close to that of *S. parasitica*, is rarely found at the hatchery. It is doubtful, therefore, that it contributes toward infections in the ponds.

DISCUSSION

Attention has been called to the general prevalence of several species of water molds in the ponds of the Lydell State Fish Hatchery. It has been shown that their zoöspores readily infect dead fish eggs and that one or more species will infect the membranes of living eggs by means of their zoöspores as well as by their hyphae. There is no doubt that the death of many thousand fish eggs in these ponds annually is due in part to the prevalence of these molds. The elimination of water molds from this and similar situations would be of great benefit to fish culture. The best method known at present to keep the fungi under control is a periodic draining and cleaning of the ponds.

SUMMARY

1. One hundred and thirty samples of water from 26 ponds, 40 samples of water from sources, and 115 samples of soil were collected from the Lydell State Fish Hatchery to determine the water-mold contamination of this hatchery.

2. A method for obtaining single-zoospore cultures of water molds is described.

3. Fourteen species of water molds were isolated from the water and the soil samples. They are identified and described.

4. It is found that *S. parasitica* Coker is more abundant in this situation than are any other species isolated from the samples.

5. The streams which supply the ponds were found to be highly contaminated with mold spores of various species, so that the contamination of the ponds and the soil of the hatchery could be traced back to these sources.

6. Experiments to determine the extent of parasitism of *S. parasitica* Coker and other molds were conducted, and certain of these molds were found to infect membranes of living fish eggs. They were found not to be parasitic on the fry of fish. One or more of these molds were shown to infect older fish at injured points and to cause the death of such fish.

CALVIN COLLEGE
GRAND RAPIDS

LITERATURE CITED

1. BARY, A. DE. 1860. Einige neue Saprolegnieen, Jahrb. f. wiss. Bot., 2: 169-192, pls. 19-21.
2. ——— 1883. Zu Pringsheims neuen Beobachtungen über den Befruchtungsact der Gattungen Achlya und Saprolegnia. Bot. Zeit., 41: 38-54.
3. ——— 1888. Species der Saprolegnieen. *Ibid.*, 46: 597-645, pls. 9-10.
4. COKER, W. C. 1923. The Saprolegniaceae, with Notes on Other Water Molds, 201 pages, 63 pls. University of North Carolina Press, Chapel Hill, North Carolina.
5. ——— AND PEMBERTON, J. D. 1908. A New Species of Achlya. Bot. Gaz., 45: 194-196, figs. 1-6.
6. GILTNER, W. 1926. Laboratory Manual in General Microbiology, 472 pages, 72 figs. John Wiley & Sons, Inc., New York.
7. HILDEBRAND, F. 1867-68. Mycologische Beiträge I. Über einige neue Saprolegnieen. Jahrb. f. wiss. Bot., 6: 249-269, pls. 15-16.

8. HUMPHREY, J. E. 1892, 1893. The Saprolegniaceae of the United States, with Notes on Other Species. Trans. Am. Phil. Soc., 17: 63-148, pls. 14-20.
9. HUXLEY, T. H. 1882. Saprolegnia in Relation to Salmon Disease. Quart. Journ. Microsc. Soc., 22: 311-315.
10. KANOUSE, B. B. 1932. A Physiological and Morphological Study of *Saprolegnia parasitica*. Mycologia, 27: 431-452, pls. 12-13.
11. KAUFFMAN, C. H. 1908. A Contribution to the Physiology of the Saprolegniaceae, with Special Reference to the Variations of the Sexual Organs. Ann. Bot., 23: 362-387.
12. MAURIZIO, A. 1894. Zur Entwicklungsgeschichte und Systematik der Saprolegnieen. Flora, 79: 109-158.
13. PIETERS, A. J. 1915. The Relation between Vegetative Vigor and Reproduction in Some Saprolegniaceae. Am. Journ. Bot., 2: 529-576, figs. 1-2.
14. — 1915. New Species of Achlya and of Saprolegnia. Bot. Gaz., 60: 483-490, pl. 21.
15. PRINGSHEIM, N. 1873. Weitere Nachträge zur Morphologie und Systematik der Saprolegnieen. Jahrb. f. wiss. Bot., 9: 191-234, pls. 17-22.

BRYOPHYTES OF THE PORCUPINE MOUNTAINS, ONTONAGON COUNTY, MICHIGAN *

GEORGE E. NICHOLS

Yale University

and

WILLIAM C. STEERE

University of Michigan

DURING August, 1935, the writers spent a week in the Porcupine Mountains, in northern Michigan, with the object of obtaining, in the limited time available, as nearly complete a list as possible of the bryophyte flora of this region. These mountains are one of the outstanding physiographic features of the state. Situated well toward the westernmost border of the Upper Peninsula, they extend for a distance of approximately twenty miles along the south shore of Lake Superior, reaching inland for perhaps a dozen miles. These and the Huron Mountains, farther east, constitute the only areas in Michigan to which the term "mountains" is consistently applied. Their geological features have been described by various authors, notably by Irving (4), and ecological reports on the vegetation have been written by Ruthven (5) and Darlington (1). Among the plants which have been listed by these two writers Ruthven includes thirteen lichens, but no bryophytes, and Darlington includes about ten mosses. More recently eight liverworts have been recorded from this region in two papers, by Steere (6) and Evans and Nichols (2), on the basis of collections made by Dr. Darlington, Dr. A. H. Smith, and Mrs. Bayard Taylor. No other published accounts dealing with the bryophytes of the Porcupines are known to the writers. Several unreported collections of both liverworts and mosses have been made in this

* Contribution from the Osborn Botanical Laboratory of Yale University and from the Department of Botany, the Herbarium, and the Biological Station of the University of Michigan.

region, however, by Dr. Darlington and Dr. E. A. Bessey, whose specimens were determined by Dr. Grout and the junior author. These will be referred to specifically in the pages which follow.

Most of the Porcupine Mountain country is very rugged and heavily wooded. Over considerable portions the forest still remains in essentially its primeval condition, being made up largely of hemlock, *Tsuga canadensis* (L.) Carr., sugar maple, *Acer saccharum* Marsh., and yellow birch, *Betula lutea* Michx. Hemlock in particular sometimes forms nearly pure stands, but in the main the upland forest consists of all three trees, variously intermixed, with basswood, *Tilia glabra* Vent., red oak, *Quercus borealis* Michx., white pine, *Pinus strobus* L., white spruce, *Picea glauca* (Moench) Voss., balsam fir, *Abies balsamea* (L.) Mill., and white cedar, *Thuja occidentalis* L., less abundant. Some of the finest forests lie along the road into the mountains. The greater part of the area has been lumbered, however, and the forests which occupy it today are very largely second growth, showing nearly everywhere the effects of repeated fires. Trails in this region are few, badly maintained, and poorly marked, with windfalls of frequent occurrence, so that access is difficult to all save those small portions of the area which lie within easy reach of the road. A new road leading into the mountains is in course of construction, but in the summer of 1935 access was by way of a rough road which was practically impassable in wet weather. This road, hereafter designated "Mountain Road," enters the area from the east and in about five or six miles climbs to the site of an old mining camp, on a shoulder of the mountains about 600 feet above and in full view of Lake Superior. It was here that the writers established their headquarters.

The most striking single physiographic feature of these mountains is a high ridge which runs parallel to the shore of Lake Superior for fully six miles, at a distance of about a mile and a half inland, rising to an elevation of from 850 to 900 feet above the lake, or about 1,450-1,500 feet above sea level. For the first mile the ascent from the lake shore to the top of this ridge is gradual, thereafter becoming steeper as the crest is approached. Beyond the crest the ridge terminates abruptly in precipitous south-facing cliffs about 200 feet high, below which are steep talus slopes of loose angular rock fragments reaching downward to the floor of the Carp River valley, about 400 feet below the summit. In this valley is Carp

Lake, or "Lake of the Clouds," somewhat over a mile long and perhaps a third of a mile wide. Beyond the valley, toward the south and southeast, rise rocky hills and ridges which attain in places an elevation of 1,421 feet above Lake Superior (2,021 feet above sea level), the highest elevation in Michigan. Among these hills, about three miles south of Carp Lake, is Little Carp Lake, or "Mirror Lake," to be referred to later. The common rock along the Lake Superior shore and along either side of the ridge, inland, is sandstone. The ridge itself is composed mainly of basalt, with both diabase and sandstone in the talus.

In the list of collections no attempt has been made to indicate exact localities for the commoner species which are of general distribution. The various collections were made jointly by the authors, with the exception of those made independently by the junior author along the road to Nonesuch Mine (designated "Nonesuch Mine Road"). All stations recorded simply as "talus slope" are on that part of the talus slope referred to above which lies immediately north and northeast of Carp Lake. The locality designated as "cedar swamp" is along the trail between Carp and Little Carp lakes, and near the latter. All determinations of liverworts have been made or verified by Dr. A. W. Evans; those of Fontinalis, by Dr. Winona H. Welch; of Grimmiaceae, by Mr. E. B. Bartram; of Plagiotheciaceae, Brachytheciaceae, Sematophyllaceae, and Hypnaceae, and a few others, by Dr. A. J. Grout; of Leskeaceae, by Dr. A. J. Sharp; of *Bryum Muhlenbeckii* Br. & Sch., by Dr. A. L. Andrews and Dr. H. N. Dixon. Credit for previous collections is given by the use of the word "also" followed by an initial for each collector. The initials D., D. and B., S., and T. stand for Darlington, Darlington and Bessey, Smith, and Taylor, respectively. The nine species and the two varieties marked with an asterisk (*) are here recorded for the first time from Michigan.

LIST OF SPECIES

REBOULIACEAE

- *GRIMALDIA RUPESTRIS (Nees) Lindenb. — Local on moist base of diabase cliffs north of Carp Lake and on faces of canyon along Nonesuch Mine Road.

MARCHANTIACEAE

- CONOCEPHALUM CONICUM (L.) Dumort. — Along banks of brook in swampy woods. Also D. and B.
- PREISSIA QUADRATA (Scop.) Nees. — Collected by Mrs. Taylor (2) on gravelly bluff along eastern edge of mountains.
- MARCHANTIA POLYMORPHA L. — Common in swamps. Also D. and B.

RICCARDIACEAE

- RICCARDIA LATIFRONS Lindb. — On rotten logs in moist woods.
- RICCARDIA MULTIFIDA (L.) S. F. Gray. — On gravelly bluff along Lake Superior (2) and clayey border of ditch along Mountain Road.
- RICCARDIA PINGUIS (L.) S. F. Gray. — At edge of brook in wet woods.

PELLIACEAE

- BLASIA PUSILLA L. — Common on moist earth bluffs or banks along shore of Lake Superior (2, 6) and Mountain Road.
- FOSSOMBRONIA FOVEOLATA Lindb. — Collected by Dr. Darlington on clay soil along shore of Carp Lake (6).
- PELLIA FABRONIANA Raddi. — On damp clay banks along Carp River.
- PELLIA NEESIANA (Gottsche) Limpr. — Collected by Dr. Darlington in 1922, growing on damp rocks in Carp River; determined by Dr. Conklin and Dr. Evans.

LOPHOZIACEAE

- CHILOSCYPHUS FRAGILIS (Roth) Schiffn. — On wet ground in cedar swamp.
- CHILOSCYPHUS PALLESCENS (Ehrh.) Dumort. — On rotten log in woods.
- CHILOSCYPHUS RIVULARIS (Schrad.) Loeske. — On stones in brooks.
- GEOCALYX GRAVEOLENS (Schrad.) Nees. — On moist logs and earth banks.
- HARPANTHUS SCUTATUS (Web. & Mohr) Spruce. — On moist logs in woods.
- JAMESONIELLA AUTUMNALIS (DC.) Steph. — On moist logs in woods. Also D. and B.

- JUNGERMANNIA LANCEOLATA Schrad. — On logs and ground in woods.
- LEIOCOLEA BADENSIS (Gottsche) Jörg. (*Lophozia badensis* Schiffn.). — On humus in moist woods.
- LEIOCOLEA HETEROCOLPA (Thed.) Buch. (*Lophozia heterocolpa* M. A. Howe). — On humus and rotten logs in woods.
- LOPHOCOLEA HETEROPHYLLA (Schrad.) Dumort. — On moist logs and banks. Also D. and B.
- LOPHOCOLEA MINOR Nees. — On rocky bluffs along shore of Lake Superior.
- LOPHOZIA BARBATA Dumort. — Common on mossy banks. Also D. and B.
- LOPHOZIA EXCISA (Dicks.) Dumort. — On boulder in woods.
- LOPHOZIA INCISA (Schrad.) Dumort. — On clayey banks along Mountain Road and on rotten wood along Nonesuch Mine Road.
- LOPHOZIA PORPHYROLEUCA (Nees) Schiffn. — On rotten logs in woods.
- LOPHOZIA VENTRICOSA (Dicks.) Dumort. — On rotten logs in woods.
- PLAGIOCHILA ASPLENIOIDES (L.) Dumort. — On damp banks and tree bases. Also D. and B.
- TRITOMARIA EXSECTIFORMIS (Breidl.) Schiffn. (*Sphenolobus exsectiformis* Steph.). — On moist soil.

CEPHALOZIELLACEAE

- *CEPHALOZIELLA RUBELLA Douin. (*C. bifida* (Schreb.) Schiffn.). — On earth in woods near Carp Lake.

CEPHALOZIACEAE

- BAZZANIA TRILOBATA (L.) S. F. Gray. — Very common on ground, logs, etc., in woods. Also D. and B.
- CALYPOGEIA NEESIANA (Massal. & Carest.) K. Müll. — On ground in woods.
- CALYPOGEIA TRICHOMANIS (L.) Corda. — On moist shaded bank in woods.
- CEPHALOZIA BICUSPIDATA (L.) Dumort. — On earth along roadside ditch.
- CEPHALOZIA CURVIFOLIA (Dicks.) Lindb. — On rotten logs in moist woods.

CEPHALOZIA MEDIA Lindb. (*C. lunulaefolia* Dumort.). — On rotten logs in woods.

CEPHALOZIA PLENICEPS (Aust.) Lindb. — On moist clay banks along Mountain Road.

LEPIDOZIA REPTANS (L.) Dumort. — On logs and banks in woods.

PTILIDIACEAE

BLEPHAROSTOMA TRICHOPHYLLUM (L.) Dumort. — On ground in moist woods.

PTILIDIUM CILIARE (L.) Nees. — Among rocks at base of talus slope. Also D. and B.

PTILIDIUM PULCHERRIMUM (Web.) Hampe. — On logs in woods.

TRICHOCOLEA TOMENTELLA (Ehrh.) Dumort. — On ground in swampy woods.

SCAPANIACEAE

SCAPANIA IRRIGUA (Nees) Dumort. — On rocky bluffs along shore of Lake Superior.

SCAPANIA MUCRONATA Buch. — On earth bank along shore of Lake Superior and on rotten log in deep woods.

RADULACEAE

RADULA COMPLANATA (L.) Dumort. — Common on trees and rocks. Also D. and T. (2).

PORELLACEAE

PORELLA PLATYPHYLLOIDEA (Schwein.) Lindb. — Common on trees and occasionally on rocks. Also D. and B.

LEJEUNEACEAE

COLOLEJEUNEA BIDDLECOMIAE (Aust.) Evans. — On trunk of white cedar near Little Carp Lake.

FRULLANIA ASAGRAYANA Mont. — On trunk of white cedar in swampy woods.

FRULLANIA BOLANDER: Aust. — Frequent on trunks of yellow birch in woods along shore of Lake Superior. Also T. (2).

FRULLANIA BRITTONIAE Evans. — Collected by Mrs. Taylor (2) on trees along eastern edge of mountain area.

FRULLANIA EBORACENSIS Gottsche. — On bark of trees. Also D. and B., and T. (2).

LEJEUNEA CAVIFOLIA (Ehrh.) Lindb. — On boulder in woods near Carp Lake and on walls of canyon along Nonesuch Mine Road.

SPHAGNACEAE

SPHAGNUM GIRGENSOHNII Russ. — On ground in cedar swamp.

SPHAGNUM MAGELLANICUM Brid. — On ground in cedar swamp.

SPHAGNUM PALUSTRE L. — On ground in cedar swamp. Also D.

SPHAGNUM SQUARROSUM Crome. — On ground in cedar swamp.

ANDREAEACEAE

ANDREAEA PETROPHILA Ehrh. — On rocks of talus slope.

GEORGIACEAE

GEORGIA PELLUCIDA (L.) Rabenh. — On rotten logs and stumps in woods. Also D. and B.

DIPHYSCIACEAE

DIPHYSCIUM SESSILE (Schmid.) Lindb. (*Webera sessilis* Lindb.). — Locally abundant on earth banks in woods.

POLYTRICHACEAE

CATHARINAEA ANGUSTATA Brid. — Open hillside woods north of Carp Lake.

CATHARINAEA UNDULATA (L.) Web. & Mohr. — On moist banks along Mountain Road.

POLYTRICHUM ALPINUM L. (*Pogonatum alpinum* Roehl.). — On ledge in woods south of Carp Lake.

POLYTRICHUM FORMOSUM Hedw. (*P. attenuatum* Menz.). — On ground in woods south of Carp Lake; previously recorded in the state only from the Douglas Lake region.

POLYTRICHUM COMMUNE L. — Frequent on ground in open situations. Also D. and B.

POLYTRICHUM JUNIPERINUM Willd. — Common on dry exposed ground. Also D.

POLYTRICHUM PILIFERUM Schreb. — Common on dry exposed ground. Also D. (1).

FISSIDENTACEAE

FISSIDENS ADIANTOIDES (L.) Hedw. — On wet earth along small stream near shore of Lake Superior. Also D. and B.

- FISSIDENS BRYOIDES (L.) Hedw. — On moist earth banks along Mountain Road and elsewhere.
- FISSIDENS CRISTATUS Wils. — On stones and earth in moist woods.
- FISSIDENS OSMUNDIOIDES (Sw.) Hedw. — On wave-washed rock ledges, often actually in the water, along the shore of Lake Superior. Determined by Dr. Grout.
- FISSIDENS VIRIDULUS (Sw.) Wahlenb. — On sandstone rocks in bed of intermittent hillside brook north of Carp Lake.

GRIMMIACEAE

- GRIMMIA ALPICOLA Hedw. var. RIVULARIS (Brid.) Broth. — On rocks in bed of stream along shore of Lake Superior and in woods. Also D.
- GRIMMIA APOCARPA (L.) Hedw. — Common on rocks of talus and elsewhere. Also D. (1).
- *GRIMMIA APOCARPA var. GRACILIS (Schleich.) Web. & Mohr. (*G. gracilis* Schleich.). — On rocks of talus near Carp Lake Mine.
- GRIMMIA COMMUTATA Hüb. (*G. ovata* Web. & Mohr). — On rocks of talus slope; previously recorded in Michigan only from Isle Royale.
- RHACOMITRIUM ACICULARE (L.) Brid. — On submerged rocks in bed of mountain stream along Nonesuch Mine Road.
- RHACOMITRIUM CANESCENS (Timm) Brid. — On moist sandstone near stream along Nonesuch Mine Road.

DICRANACEAE

- CERATODON PURPUREUS (L.) Brid. — Common on dry substrata of every description, mostly in the open. Also D. (1).
- DICRANELLA HETEROMALLA (L.) Schimp. — Abundant on moist earth banks along Mountain Road.
- DICRANELLA SCHREBERI (Sw.) Schimp. — On moist clayey soil bordering ditch along Mountain Road.
- ONCOPHORUS POLYCARPUS (Hedw.) Brid. — On rotten log in woods along shore of Lake Superior.
- ONCOPHORUS WAHLENBERGII Brid. — On logs in moist woods. Also D. and B.
- DICRANUM BONJEANII De Not. — On rotten logs in woods. Also D.
- DICRANUM DRUMMONDII C. Müll. — Among rocks of talus slope.
- DICRANUM FLAGELLARE Hedw. — Common on rotten wood.

- DICRANUM FUSCESCENS Turn. — On ground in woods along shore of Lake Superior.
- DICRANUM LONGIFOLIUM Ehrh. — Frequent to common on mostly rocky substrata. Also D. and B.
- DICRANUM MONTANUM Hedw. — Common on rotten wood. Also D.
- DICRANUM MUEHLENBECKII Br. & Sch. — Along crest of diabase cliffs overhanging Carp Lake; heretofore recorded in Michigan only from Emmet Co. Determination confirmed by Mr. E. B. Bartram.
- DICRANUM RUGOSUM (Hoffm.) Br. & Sch. — Common on ground in moist woods. Also D. and B.
- DICRANUM SCOPARIUM (L.) Hedw. — Common on various substrata. Also D. and B.
- DICRANUM SPURIUM Hedw. — On rocks along base of talus slope.
- DICRANUM VIRIDE (Sull. & Lesq.) Lindb. — Frequent on logs and trees in woods.
- DICHODONTIUM PELLUCIDUM (L.) Schimp. — Locally abundant on wet rocks along shore of Lake Superior.
- LEUCOBRYUM GLAUCUM (L.) Schimp. — In woods along shore of Lake Superior. Also D. and B.

POTTIACEAE

- HYMENOSTYLIUM CURVIROSTRE (Ehrh.) Lindb. — Local on moist cliff north of Carp Lake.
- TORTELLA CAESPITOSA (Schwaegr.) Limpr. — Locally abundant on ground in hemlock-hardwood forest.
- TORTELLA FRAGILIS (Drumm.) Limpr. — On rocky shore of Lake Superior; first record from the Upper Peninsula.
- TORTELLA TORTUOSA (L.) Limpr. — On talus slope. Also D. (1).
- DIDYMODON RUBELLUS (Hoffm.) Br. & Sch. — Moist bluffs along shore of Lake Superior.
- TORTULA RURALIS (L.) Ehrh. — Frequent on dry exposed summits and lake bluffs.

ENCALYPTACEAE

- ENCALYPTA CILIATA (Hedw.) Hoffm. — Moist ledge along shore of Lake Superior.
- ENCALYPTA CONTORTA (Wulf.) Lindb. — Local on moist base of diabase cliffs north of Carp Lake.

ORTHOTRICHACEAE

- AMPHIDIUM LAPPONICUM (Hedw.) Schimp. — On wall of deep canyon along Nonesuch Mine Road; previously known in Michigan only from Isle Royale.
- DRUMMONDIA PROREPENS (Hedw.) Jennings (*D. clavellata* Hook.). — Local on trunk of sugar maple in hardwood-hemlock forest along Mountain Road; heretofore known from but one other locality in the state and not at all from the Upper Peninsula.
- ORTHOTRICHUM ANOMALUM Hedw. — On rocks of copper-mine dump north of Carp Lake.
- ORTHOTRICHUM OBTUSIFOLIUM Schrad. — On bark of sugar maple in mixed hemlock-hardwood forest.
- ORTHOTRICHUM SPECIOSUM Nees. — On bark of trees; the commonest species of the genus. Also D. and B.
- ULOTA CRISPA Brid. — Frequent on bark of trees.

FUNARIACEAE

- FUNARIA HYGROMETRICA (L.) Sibth. — Common in dry exposed places. Also D. (1).

BRYACEAE

- POHLIA CRUDA (L.) Lindb. (*Webera cruda* Bruch.). — On moist rock along Nonesuch Mine Road.
- POHLIA NUTANS (Schreb.) Lindb. (*Webera nutans* Hedw.). — On ground, mostly in dry open situations.
- POHLIA PROLIGERA Lindb. (*Webera proligera* Kindb.). — On rocky bluffs along shore of Lake Superior. According to Andrews (3, II: 199), no authentic records are known for this species in the United States east of northern Michigan, where it appears to be not uncommon along exposed bluffs and ledges near the shore of Lake Superior.
- POHLIA WAHLENBERGII (Web. & Mohr) Andrews. (*Mniobryum albicans* (Wahlenb.) Limpr.). — Common in crevices of wave-washed rocks along shore of Lake Superior. Also D. and B.
- LEPTOBRYUM PYRIFORME (L.) Wils. — On moist earth in open places. Also D. (1).
- BRYUM ARGENTEUM L. — Frequent on dry rocky ridges and on rocks along shore of Lake Superior. Also D.

- BRYUM BIMUM Schreb. — On ground in swamps. Also D. and B.
BRYUM CAESPITICUM L. — Frequent on exposed bluffs and banks.
Also D. and B.
BRYUM CAPILLARE L. — Frequent in rock crevices and on earth,
both in woods and in the open.
BRYUM MUEHLENBECKII Br. & Sch. — Locally abundant on wet
rocks along shore of Lake Superior; previously recorded in
Michigan only from Isle Royale.
RHODOBRYUM ROSEUM (Weis) Limpr. — On bank in woods near
Carp Lake.

MNIACEAE

- MNIUM AFFINE Bland. — Moist earth in woods near Carp Lake.
MNIUM CILIARE (Grev.) Lindb. — Moist bank in woods along
shore of Lake Superior. Also D. and B.
MNIUM CINCLIDIODES (Blytt) Hüben. — Swampy woods near Lit-
tle Carp Lake.
MNIUM CUSPIDATUM (L.) Leyss. — On logs and ground in woods.
Also D.
MNIUM MEDIUM Br. & Sch. — Growing on ground in moist shaded
depressions.
MNIUM ORTHORRHYNCHUM Brid. — Rocky bluffs and logs along
shore of Lake Superior.
MNIUM PUNCTATUM (L.) Hedw. — On rocks in brook near Little
Carp Lake.
MNIUM PUNCTATUM var. ELATUM Schimp. — On wet ground in
cedar swamp. Also D. and B.
MNIUM SPINULOSUM Br. & Sch. — Common on logs in woods.
Also D. and B.
MNIUM STELLARE Reich. — At base of tree along moist shaded
bank. Also D. and B.

AULACOMNIACEAE

- AULACOMNIUM PALUSTRE (L.) Schwaegr. — Swampy woods near
shore of Lake Superior.

BARTRAMIACEAE

- PLAGIOPUS OEDERI (Gunn.) Limpr. — On walls of deep canyon
along Nonesuch Mine Road.

BARTRAMIA POMIFORMIS (L.) Hedw. — Occasional on rocky bluffs along Lake Superior and common in canyons along Nonesuch Mine Road. Also D. and B.

PHILONOTIS FONTANA (L.) Brid. — Frequent along wet rocky shores of Lake Superior. Also D.

FONTINALACEAE

FONTINALIS ANTIPYRETICA (L.) Hedw. — Attached to stones in rapid brook south of Carp Lake.

FONTINALIS ANTIPYRETICA var. *GIGANTEA* Sull. — Attached to sticks in slow stream south of Carp Lake and in wet woods at Nonesuch Mine.

**FONTINALIS MISSOURICA* Card. — On sides of springy rock pool along shore of Lake Superior.

**FONTINALIS NITIDA* Lindb. — Growing associated with the preceding species.

DICHELYMA PALLESCENS Br. & Sch. — Attached to rock in dried-up, open swamp pool along shore of Lake Superior.

CLIMACIACEAE

CLIMACIUM AMERICANUM Brid. — On periodically wet ground in woods along shore of Lake Superior.

CLIMACIUM DENDROIDES (L.) Web. & Mohr. — Common in wet woods.

HEDWIGIACEAE

HEDWIGIA ALBICANS (Web.) Lindb. — Frequent on exposed rocks. Also D.

LEUCODONTACEAE

LEUCODON SCIUROIDES (L.) Schwaegr. — Common on bark of sugar maple and other trees and occasional on shaded talus blocks and cliffs. Also D.

NECKERACEAE

NECKERA PENNATA (L.) Hedw. — Common on bark of sugar maple and other trees; rarely on shaded rocks. Also D.

HOMALIA JAMESII Schimp. — Locally abundant on mossy banks of woodland ravine near Little Carp Lake and on boulders, logs, and tree bases in forest along Nonesuch Mine Road.

THELIACEAE

MYURELLA CAREYANA Sull. — On canyon walls along Nonesuch Mine Road.

MYURELLA JULACEA (Vill.) Br. & Sch. — Local on diabase cliffs north of Carp Lake.

ANOMODON ATTENUATUS (Schreb.) Hüben. — Common on rocks and bases of trees.

ANOMODON MINOR (Beauv.) Lindb. — On trunks of sugar maple and other hardwoods.

ANOMODON ROSTRATUS (Hedw.) Schimp. — On dry rocky ledges in woods. Also D. and B.

ANOMODON RUGELII (C. Müll.) Keissl. — *A. apiculatus* Br. & Sch. — On shaded boulder in hemlock forest.

THUIDIACEAE

THUIDIUM ABIETINUM (L.) Br. & Sch. — Common on dry ledges along shore of Lake Superior and on talus slope. Also D. (1).

THUIDIUM DELICATULUM (L.) Mitt. — Common in moist to swampy woods. Also D. and B.

THUIDIUM MICROPHYLLUM (Sw.) Best. — Collected by Dr. Darlington and Dr. Bessey on rotten wood near Little Carp Lake.

THUIDIUM PHILIBERTI Limpr. — A common species in hemlock-hardwood forests along Mountain Road and elsewhere, growing on the ground; frequently associated with *T. delicatulum*, but easily distinguished from this with a hand lens by its filiform-acuminate leaves. In Michigan heretofore known only from Isle Royale.

HETEROCLADIUM SQUARROSULUM (Voit) Lindb. — One of the commonest terrestrial mosses of dry to moist woods, growing also in open situations. Also D. and B.

LESKEACEAE

LESKEA NERVOSA (Schwaegr.) Myrin. — Frequent on rocks and tree trunks, both in woods and in the open. Also D. and B.

LESKEA POLYCARPA Ehrh. — Collected by Dr. Darlington and Dr. Bessey on bark of black ash in a tamarack swamp.

*LESKEA TECTORUM (A. Braun) Lindb. — Locally abundant on rocks in crannies of talus slope north of Carp Lake. According to

Sharp (3, III:195), this is primarily a species of the Rocky Mountains and the Pacific Coast, extending eastward to Lake Superior.

LINDBERGIA BRACHYPTERA (Mitt.) Kindb. var. AUSTINII (Sull.) Grout. — On dead tree trunk in woods near Carp Lake Mine; previously known from but two localities in the state, both in the Lower Peninsula.

*PSEUDOLESKEA OLIGOCLADA Kindb. — On wooded rocky slope below Carp Lake Mine; a western species characterized by Sharp (3, III:187) as ranging from British Columbia to Colorado and Utah.

PTERIGYNANDRUM FILIFORME Hedw. — On rocky ledges and trees along shore of Lake Superior.

AMBLYSTEGIACEAE

LEPTODICTYUM RIPARIUM (L.) Warnst. — In a rock pool along the shore of Lake Superior. Also D. and B.

LEPTODICTYUM RIPARIUM var. LONGIFOLIUM (Schultz) Grout. — On stones in dried-up woodland swamp pool south of Carp Lake.

AMBLYSTEGIUM JURATZKANUM Schimp. — On damp shaded rocks and logs. Also D. and B.

AMBLYSTEGIUM SERPENS (L.) Br. & Sch. — On moist ground in forest.

AMBLYSTEGIUM VARIUM (Hedw.) Lindb. — On moist earth in woods. Also D. (1).

HYGROAMBLYSTEGIUM IRRIGUUM (Wils.) Loeske. — Common on periodically wet rocks in brooks. Also D. and B.

HYGROAMBLYSTEGIUM FLUVIATILE (Sw.)¹ Loeske. — Collected by Dr. Darlington and Dr. Bessey on rocks in mountain brook.

HYGROAMBLYSTEGIUM ORTHOCLADON (Beauv.) Grout. — In beach pools along rocky shore of Lake Superior. Also D. and B.

CAMPYLUM CHRYSOPHYLLUM (Brid.) Bryhn. — On moist stream banks and elsewhere in moist woods. Also D. and B.

CAMPYLUM HISPIDULUM (Brid.) Mitt. — Frequent on ground in woods.

*HYGROHYPNUM MOLLE (Schimp.) Loeske. — On rocks in small brook along shore of Lake Superior. According to Grout (3, III:93), this is an arctic-alpine species of the "northwestern U. S. and western Canada from the Rocky Mts. northward and westward."

- HYGROHYPNUM OCHRACEUM (Turn.) Loeske. — On wet rocks in a brook and along rocky shore of Lake Superior.
- HYGROHYPNUM PALUSTRE (Huds.) Loeske. — Attached to rocks in springy brook along shore of Lake Superior.
- CALLIERGON CORDIFOLIUM (Hedw.) Kindb. — On ground in wooded swamp south of Carp Lake. Also D.
- CALLIERGONELLA SCHREBERI (Willd.) Grout. (*Hypnum schreberi* Willd.). — Common on ground and logs in woods.
- *DREPANOCLADUS ADUNCUS (Hedw.) Warnst. f. AQUATICUS (Sanio) Warnst. — In rock pool along shore of Lake Superior.
- DREPANOCLADUS ADUNCUS var. POLYCARPUS (Bland.) Warnst. — Swampy woods south of Carp Lake.
- DREPANOCLADUS FLUITANS (L.) Warnst. — In dried-up pond hole along shore of Lake Superior.
- DREPANOCLADUS UNCINATUS (Hedw.) Warnst. — On mossy bank in woods along shore of Lake Superior. Also D. and B.

BRACHYTHECIACEAE

- BRYHNIA NOVAE-ANGLIAE (Sull. & Lesq.) Grout. — On wet ground along woodland brook south of Carp Lake. Also D. and B.
- EURYNCHIUM DIVERSIFOLIUM (Schleich.) Br. & Sch. — On ground along wooded slope near Carp Lake.
- EURYNCHIUM RUSCIFORME (Neck.) Milde. — Common on wet or periodically inundated rock surfaces in brooks and ravines. Also D. and B.
- EURYNCHIUM STRIGOSUM (Hoffm.) Br. & Sch. — On ground along wooded slope near Carp Lake. Also D.
- *BRACHYTHECIUM BESTII Grout. (*B. pacificum* (R. & C.) Grout.). — Frequent on stones and banks in moist woods, bearing a close resemblance to *B. reflexum*. According to Grout (3, III: 45), this is primarily a species of the northern Pacific slope, found also in the northern Rockies, and in the East previously known from northern Nova Scotia and Newfoundland.
- BRACHYTHECIUM CAMPESTRE Br. & Sch. — On humus and rotten wood in wet to moist woods.
- BRACHYTHECIUM OXYCLADON (Brid.) Jaeg. & Sauerb. — On humus and tree bases in woods. Also D. and B.
- BRACHYTHECIUM PLUMOSUM (Sw.) Br. & Sch. — On rocky ledges along shore of Lake Superior.

BRACHYTHECIUM POPULEUM (Hedw.) Br. & Sch. — On rocks and soil in rocky woods, and on lake bluffs. Also D. and B.

BRACHYTHECIUM REFLEXUM (Web. & Mohr) Br. & Sch. — Common on rocks, logs, and humus in the woods.

BRACHYTHECIUM RIVULARE Br. & Sch. — Abundant on stones in and along woodland streams and on wet banks of ditch along Mountain Road. Also D.

BRACHYTHECIUM RUTABULUM (L.) Br. & Sch. — Frequent on humus-covered stones and on rotten stumps in moist woods. Also D.

BRACHYTHECIUM SALEBROSUM (Hoffm.) Br. & Sch. — On rocks and on ground both in the open and in the woods.

ENTODONTACEAE

ENTODON SEDUCTRIX (Hedw.) C. Müll. — Collected by Dr. Darlington and Dr. Bessey; first record for the Upper Peninsula.

PLAGIOTHECIACEAE

PLAGIOTHECIUM DENTICULATUM (L.) Br. & Sch. — On ground in moist woods. Also D. and B.

PLAGIOTHECIUM LAETUM Br. & Sch. — On rocky ledge in woods near Little Carp Lake.

*PLAGIOTHECIUM MUELLERIANUM Schimp. — On moist rock ledge in woods near Little Carp Lake.

PLAGIOTHECIUM ROESEANUM (Hampe) Br. & Sch. — On shaded earth bank along shore of Lake Superior.

PLAGIOTHECIUM SYLVATICUM (Huds.) Br. & Sch. — On ground in moist woods.

PLAGIOTHECIUM TURFACEUM (Lindb.) Lindb. — On humus in the forest. Also D.

SEMATOPHYLLACEAE

HETEROPHYLLIUM HALDANIANUM (Grev.) Kindb. — Common on logs and on ground in woods. Also D. and B.

BROTHERELLA DELICATULA (James) Fleisch. — On humus in woods along shore of Lake Superior.

BROTHERELLA RECURVANS (Michx.) Fleisch. — On ground in woods. Also D. and B.

HYPNACEAE

HYPNUM CRISTA-CASTRENSIS L. — On moist logs. Also D. and B.

HYPNUM FERTILE Sendt. — On humus in mossy woods along bluffs

- facing Lake Superior. This is the first authentic record for this species in the Upper Peninsula and the second in Michigan.
- HYPNUM PALLESCENS* (Hedw.) Br. & Sch. — On tree bases, logs, and stones in the woods.
- HYPNUM PATIENTIAE* Lindb. — On ground and periodically wet logs in swampy woods near shore of Lake Superior.
- HYPNUM REPTILE* Michx. — On tree bases, logs, and stones in woods.
- HOMOMALLIUM ADNATUM* (Schimp.) Loeske. — Collected by Dr. Darlington.
- AMBLYSTEGIELLA SUBTILIS* (Hedw.) Loeske. — Common on tree bases in woods.
- PYLAISIA INTRICATA* (Hedw.) Br. & Sch. — On tree trunks in woods.
- PYLAISIA SELWYNII* Kindb. (*P. schimperi* Card.). — Frequent on trunks of hardwoods and occasional on shaded talus blocks.
- PYLAISIA SUBDENTICULATA* Schimp. — On trunks of hardwoods.
- PLATYGIRIUM REPENS* (Brid.) Br. & Sch. — Common on tree trunks, logs, and stones, both in woods and in the open. Also D.

HYLOCOMIACEAE

- HYLOCOMIUM PYRENAICUM* (Spruce) Lindb. — On stones in moist upland forests; apparently a not uncommon species in hardwood forests of the Upper Peninsula. Also D. and B.
- HYLOCOMIUM SPLENDENS* (Hedw.) Br. & Sch. — On ground in moist to wet mossy woods; frequent.
- RHYTIDIADELPHUS TRIQUETRUS* (L.) Warnst. — On ground in woods along shore of Lake Superior and elsewhere; frequent.

The total number of bryophytes here recorded from the Porcupine Mountains is 219, comprising 52 liverworts and 167 mosses.

LITERATURE CITED

1. DARLINGTON, H. H. 1931. Vegetation of the Porcupine Mountains, Northern Michigan. Pap. Mich. Acad. Sci., Arts and Letters, 13 (1930): 9-65, 27 pls., 2 maps, 11 figs.
2. EVANS, A. W., AND NICHOLS, G. E. 1935. The Liverwort Flora of the Upper Michigan Peninsula. Bryologist, 38: 81-91.
3. GROUT, A. J. 1931-36. Moss Flora of North America. Vol. I, Part 1,

- Vol. II, Parts 1-3, and Vol. III. Newfane, Vermont. (Remaining parts not yet published.)
4. IRVING, R. D. 1883. The Copper-bearing Rocks of Lake Superior. U. S. Geol. Surv., Mon. 5.
 5. RUTHVEN, A. G. 1906. An Ecological Survey in the Porcupine Mountains and Isle Royale, Michigan. Geol. Surv. Mich., Ann. Rep. for 1905, 7: 3-133, 21 figs.
 6. STEERE, W. C. 1934. Unreported or Otherwise Interesting Bryophytes from Michigan. Bryologist, 37: 57-62.

PRELIMINARY NOTES ON THE DESMIDS OF ISLE ROYALE, MICHIGAN

GERALD W. PRESCOTT

IT HAS been the writer's opportunity to examine samples of algae taken in connection with a biological survey of Isle Royale authorized by the Fifty-fifth Legislature of the State of Michigan. The material was collected in the summer of 1930 by Mr. J. L. Lowe, of the University of Michigan. In this paper attention has been directed entirely toward the desmid flora represented in the samples.

This preliminary list of desmids from the small number of samples which have been examined to date is indicative of the abundance of these plants in the area. The topography of the island provides suitable aquatic habitats for a rich algal flora, and the acidity of the water is conducive to a luxuriant growth of desmids. The pH range for the bodies of water in which desmids occur is from 6.0 to 7.2, with most of the habitats showing a range from 6.6 to 6.8. Those samples which have the most species and the largest number of individuals are from bodies of water possessing a pH of 6.0 and, significantly, are habitats for *Utricularia*. This plant is an almost unfailing indication of a luxuriant desmid flora.

From having examined a number of samples representing widely separated stations in the area, one may conclude that the desmids here are more like the New England and northern Canada floras than the Wisconsin and the western. Whether or not this is actually the case will be determined only after a complete checking of all samples has been made. However, some forms previously reported only from Minnesota appear here. A number of plants in the Isle Royale collections are apparently undescribed species, while others are recorded for the first time in North America. The writer expects to publish an extended list of Isle Royale desmids, together with critical remarks and distribution data.

LIST OF SPECIES

CYLINDROCYSTIS DIPLOSPORA Lund.; West and West, *British Desmidiaceae*, I: 61, Pl. 4, Figs. 40-41. 1904.

Wall smooth. Width 30.4 μ , at constriction 24.7 μ , length 60.6 μ . Pl. XIX, Fig. 16. Moose Lake. New record for Michigan.

CYLINDROCYSTIS DIPLOSPORA var. MAJOR W. West; West and West, *British Desmidiaceae*, I: 61, Pl. 4, Figs. 42-43. 1904.

Width 51 μ , length 121 μ , isthmus 35 μ . Marsh near trail to Tobin Harbor. New record for Michigan.

SPIROTAENIA CONDENSATA De Bréb.; G. M. Smith, *Phytoplankton Inland Lakes Wis.*, Part II: 6, Pl. 52, Fig. 4. 1924.

Very long and sometimes strongly curved. Width 23 μ , length 250-300 μ . Moose Lake.

NETRIUM DIGITUS (Ehr.) Itzigs. & Rothe; West and West, *British Desmidiaceae*, I: 64, Pl. 6, Figs. 14-16. 1904.

Width 42 μ , length 191 μ . Moose Lake.

PENIUM CHRYSODERMA Borge; Dick, *Bot. Archiv*, 3, Pl. 4, Fig. 1.

Cells 70 μ wide, 25 μ long. Hidden Lake. New record for Michigan.

CLOSTERIUM COSTATUM Corda; West and West, *British Desmidiaceae*, I: 120, Pl. 13, Figs. 1-3. 1904.

Width 50 μ , length 350 μ . Moose Lake.

CLOSTERIUM INTERMEDIUM Ralfs; West and West, *British Desmidiaceae*, I: 125, Pl. 14, Figs. 1-5. 1904.

Width 25 μ , length 206 μ , poles 7.8 μ wide. Moose Lake.

CLOSTERIUM LIBELLULA Focke (*Penium Libellula* (Focke) Nordstedt); West and West, *British Desmidiaceae*, I: 73, Pl. 7, Figs. 6-7.

Width 35 μ , length 220 μ . Moose Lake.

CLOSTERIUM LIBELLULA Focke var. INTERMEDIUM Roy & Biss.; West and West, *British Desmidiaceae*, I: 74, Pl. 7, Fig. 11. 1904.

Width 23.4 μ , length 129 μ . Moose Lake. New record for Michigan.

CLOSTERIUM LUNULA f. MINOR W. & G. S. West; West and West, *British Desmidiaceae* I: 151. 1904.

Width 70 μ , length 390 μ , poles 13.6 μ wide. Slightly larger than measurements given by the Wests, otherwise identical. Pl. XIX, Figs. 4-5. Lake Ritchie.

CLOSTERIUM PSEUDODIANAE Roy; West and West, *British Desmidiaceae*, I: 132, Pl. 15, Figs. 7-8. 1904.

Width 14 μ , length 200 μ . Wallace Lake.

CLOSTERIUM SETACEUM Ehr.; West and West, *British Desmidiaceae*, I: 190, Pl. 26, Figs. 9-13. 1904.

Width 11.7 μ , length 312 μ . Pl. XIX, Fig. 8. Moose Lake. New record for Michigan.

CLOSTERIUM TURGIDUM Ehr.; West and West, *British Desmidiaceae*, I: 170, Pl. 22, Figs. 4-5. 1904.

Width 54.6 μ , length 624 μ , poles 13.6 μ wide. Pl. XIX, Figs. 6-7. Hidden Lake. New record for Michigan.

Closterioides, gen. nov.¹ Cells crescent-shaped, strongly curved, slightly attenuated to broadly rounded poles, which bear a single, stout spine; cell wall without a girdle band; chloroplasts with longitudinal ridges; pyrenoids large, in series or irregularly scattered; terminal vacuole absent(?).

Closterioides spinosus, sp. nov.² Cells of medium size, lunate, the outer margin more strongly curved than the inner; cell wall colorless, smooth or with sparsely scattered concretions (calcareous deposits?); chloroplasts 2 in each cell, with 2 or 3 longitudinal ridges showing; pyrenoids arranged in 3 or 4 irregular series. Width 58-62 μ , length (distance between apices) 140-148 μ , spines 4.5-11.5 μ long. Pl. XIX, Figs. 1-3. Moose Lake.

The form of this plant suggests *Tetraëdron cuspidatum* (Bailey) Wille. The Closterium-like morphology of the chloroplast and its contained pyrenoids, and the transverse break in the wall in the midregion, together with the manner in which a new semicell is built after cell division, identify this puzzling plant as a desmid. The peculiar arrangement of pyrenoids, the ap-

¹ *Closterioides*, gen. nov. — Cellulae lunatae, valde curvatae, gradatim attenuatae ad polos late rotundatos, polo utroque spinulam fortem unicam gerente; membrana sine zona media; massa chlorophyllacea in longitudine striata; pyrenoidibus magnis, vel in serie vel irregulariter dispersis; desunt vacuola terminalia(?).

² *Closterioides spinosus*, sp. nov. — Cellulae mediocres, lunatae, margine exteriori plus quam interiori curvato; membrana incolori, vel glabra vel granulis (materiam calcariam depositam habente?), sparse obsessa; massis chlorophyllaceis unicuique cellulae binis, bis terve striatis; pyrenoidibus in tres quattuorve series irregulariter dispositis. Lat. 58-62 μ , long. 140-148 μ inter apices, spinulae 4.5-11.5 μ longae. Tab. XIX, Figg. 1-3.

- parent lack of a terminal vacuole, and the consistent occurrence of the stout, terminal spines are characters which seem to warrant separating it from the genus *Closterium*. The writer hopes to obtain living material for further examination of this species.
- PLEUROTOAENIUM CORONATUM (De Bréb.) Rab.; West and West, *British Desmidiaceae*, I: 199, Pl. 27, Figs. 16-18. 1904.
Width 40 μ , length 400 μ . Moose Lake.
- PLEUROTOAENIUM CORONATUM var. NODULOSUM (De Bréb.) W. West; West and West, *British Desmidiaceae*, I: 200, Pl. 28, Figs. 5-8. 1904.
Width 58.7 μ , length 507 μ . Hidden Lake. New record for Michigan.
- PLEUROTOAENIUM NODOSUM (Bailey) Lundell; Smith, *Phytoplankton Inland Lakes Wis.*, Part II: 16, Pl. 54, Fig. 1. 1924.
Width 45 μ , length 285 μ . Moose Lake.
- PLEUROTOAENIUM TRABECULA (Ehr.) Naeg.; West and West, *British Desmidiaceae*, I: 209, Pl. 30, Figs. 11-13. 1904.
Width 30 μ , length 400 μ . Wallace Lake.
- COSMARIUM BOTRYTIS Menegh.; West and West, *British Desmidiaceae*, IV: 1, Pl. 96, Figs. 1-2, 5-15. 1912.
Width 55 μ , length 70 μ . Hidden Lake. New record for Michigan.
- COSMARIUM CONNATUM De Bréb.; West and West, *British Desmidiaceae*, III: 25, Pl. 67, Figs. 15-17. 1908.
Width 62.4 μ , length 81.9 μ , isthmus 54.6 μ . Moose Lake.
New record for Michigan.
- COSMARIUM CRENATUM Ralfs; West and West, *British Desmidiaceae*, IV: 35, Pl. 98, Figs. 9-12. 1912.
Width 19 μ , length 26.6 μ , isthmus 7.5 μ . Hidden Lake.
- COSMARIUM ELOISEANUM Wolle; West and West, *Trans. Linn. Soc. Bot.*, 5: 248, Pl. 15, Fig. 22.
Width 70.2 μ , length 95.7 μ , isthmus 19.5 μ . Moose Lake.
New record for Michigan.
- COSMARIUM MARGARITATUM (Lund.) Roy & Biss.; West and West, *British Desmidiaceae*, IV: 18, Pl. 99, Figs. 8, 10. 1912.
Width 60 μ , length 70 μ , isthmus 21 μ . Moose Lake.
- COSMARIUM MARGARITIFERUM Menegh.; West and West, *British Desmidiaceae*, III: 199, Pl. 83, Figs. 4-11. 1908.
Width 46 μ , length 55 μ , isthmus 14 μ . Moose Lake.

COSMARIUM OCHTHODES var. AMOEBUM W. West; West and West, *British Desmidiaceae*, IV: 11, Pl. 98, Figs. 4-6. 1912.

Width 62.4 μ , length 81.9 μ , isthmus 23.4 μ . Moose Lake. New record for Michigan.

COSMARIUM OVALE Ralfs; West and West, *British Desmidiaceae*, III: 267, Pl. 92, Fig. 1. 1908.

This form shows rows of granules across the base of the semicell. Moose Lake.

COSMARIUM PACHYDERMUM Lund.; Grönblad, *Acta Soc. pro Fauna et Flora Fenn.*, 55, Pl. 2, Figs. 47-48. 1924.

Width 82 μ , length 105.3 μ , isthmus 39 μ . Hidden Lake.

COSMARIUM PYRAMIDATUM De Bréb.; West and West, *British Desmidiaceae*, II: 199, Pl. 64, Figs. 5-7. 1905.

Width 51.3 μ , length 79 μ , isthmus 19 μ . Hidden Lake.

COSMARIUM SPECIOSUM var. SIMPLEX Nordstedt; West and West, *British Desmidiaceae*, III: 250, Pl. 89, Fig. 6.

Width 26.6 μ , length 43.7 μ , isthmus 17 μ . Hidden Lake. New record for Michigan.

COSMARIUM SUBREINSCHII var. OCELLATUM W. & G. S. West; West and West, *Trans. Linn. Soc. Bot.*, 6, Pl. 20, Figs. 32-33. 1902.

Width 16 μ , length 32 μ , isthmus 5 μ . Moose Lake. New record for Michigan.

COSMARIUM TETRAOPHTHALMUM De Bréb.; West and West, *British Desmidiaceae*, III: 270, Pl. 95, Figs. 4-7. 1908.

Width 82 μ , length 117 μ , isthmus 24 μ . Wallace Lake.

COSMARIUM VENUSTUM var. EXCAVATUM (Eichl. & Gutw.) W. West. Forma.

Semicell with a large scrobiculation in the center and one in either undulation at the margin. Width 25.4 μ , length 36 μ , isthmus 5.8 μ . Pl. XIX, Fig. 24. Moose Lake. New record for Michigan.

Except for its smaller size and the presence of the lateral scrobiculations this plant resembles f. *duplo-major* Gutw. of var. *excavatum*. The latter character is not figured or mentioned for any of the forms of *C. venustum* that I have been able to find on record.

ARTHRODESMUS CONVERGENS Ehr.; West and West, *British Desmidiaceae*, IV: 106, Pl. 116, Figs. 5-16. 1912.

Width (without spines) 39 μ , length 35 μ , isthmus 9.5 μ . Moose Lake.

ARTHRODESMUS INCUS var. EXTENSUS Anders.; Smith, *Phytoplankton Inland Lakes Wis.*, Part II: 132, Pl. 85, Figs. 23-26. 1924.

Width 45 μ , length (including spines) 24 μ , isthmus 5-6 μ . Pl. XIX, Fig. 25. Moose Lake. New record for Michigan.

ARTHRODESMUS TRIANGULARIS Lag.; Smith, *Phytoplankton Inland Lakes Wis.*, Part II: 133, Pl. 86, Fig. 1. Var.?

Cells with widely open sinus and narrowly elongated isthmus; semicells triangular, apex concave; spines short and upwardly diverging. Width 19.5 μ , length 23.4 μ , isthmus 6.0 μ . Pl. XIX, Fig. 11. Moose Lake.

XANTHIDIUM ANTILOPAEUM (De Bréb.) Kuetz.; West and West, *British Desmidiaceae*, IV: 63, Pl. 108, Figs. 7-18. 1912.

Width 85 μ , length 82 μ , isthmus 15 μ . Moose Lake.

XANTHIDIUM ANTILOPAEUM var. POLYMAZUM Nordst.; West and West, *British Desmidiaceae*, IV: 67, Pl. 108, Fig. 19. 1912.

Width 76 μ , length 75 μ , isthmus 16 μ . Moose Lake. New record for Michigan.

XANTHIDIUM CRISTATUM De Bréb.; West and West, *British Desmidiaceae*, IV: 70, Pl. 110, Figs. 8-9. 1912.

Width 46 μ , length 64 μ , isthmus 11 μ . Moose Lake.

XANTHIDIUM CRISTATUM var. UNCINATUM De Bréb.; West and West, *British Desmidiaceae*, IV: 73, Pl. 111, Figs. 2-4. 1912.

Width 65 μ , length 73 μ , isthmus 16 μ . Wallace Lake. New record for Michigan.

STAURASTRUM ALTERNANS De Bréb.; Smith, *Phytoplankton Inland Lakes Wis.*, Part. II: 70, Pl. 68, Fig. 4. 1924.

Width 35 μ , length 35 μ . Moose Lake.

STAURASTRUM ARACHNE Ralfs var.

Width (including arms) 39 μ , length 27.3 μ , isthmus 15 μ . Pl. XIX, Figs. 13-14.

The shape of the semicell and the character of the sinus seem to identify this as a variety of *arachne*. The recurved arms and the strong undulations of the margins, together with the distinct enlargement at the base of the arms as seen in vertical view, present a combination of characteristics unlike those of any of the described varieties of *arachne*.

STAURASTRUM ARCUATUM Nordstedt; Homfeld, *Pflanzenforschung*, 12: 69, Pl. 8, Figs. 89-91. 1929.

Width (including arms) 37 μ , length 32 μ . Pl. XIX, Figs.

18-19. Small pool in Sphagnum swamp. New record for Michigan.

STAURASTRUM BRASILIENSE var. LUNDELLII W. & G. S. West; Smith, *Phytoplankton Inland Lakes Wis.*, Part II: 120, Pl. 82, Figs. 3-5. 1924.

Width 148 μ , length (including spines) 140 μ . Moose Lake. New record for Michigan.

STAURASTRUM BREBISSEII var. MAXIMUM Cedercreutz, *Mem. Soc. pro Fauna et Flora Fenn.*, 7: 245, text figures 14-15. 1932.

Width 85.5 μ , length 87 μ , isthmus 4 μ . Mud flat on Passage Island. New record for Michigan.

STAURASTRUM CAPITULUM var. SPETSBERGENSE (Nordst.) Cooke; West and West, *British Desmidiaceae*, IV: 126, Pl. 118, Fig. 8. 1912.

Width 32 μ , length 50 μ . Slightly larger than usually described. Dripping cliff, among mosses. Passage Island. New record for Michigan.

STAURASTRUM CORNUTUM Archer; Grönblad, *Acta Soc. pro Fauna et Flora Fenn.*, 47, Pl. 2, Figs. 27-28. 1920.

Width 50.7 μ , length 40 μ , isthmus 15.6 μ . Pl. XIX, Figs. 22-23. Moose Lake. New record for Michigan.

STAURASTRUM CUSPIDATUM De Bréb.; Smith, *Phytoplankton Inland Lakes Wis.*, Part II: 74, Pl. 68, Figs. 27-34. 1924.

Width 23 μ , length 27.3 μ , isthmus 7.8 μ . Pl. XIX, Figs. 20-21. Moose Lake.

STAURASTRUM DEJECTUM De Bréb.; Smith, *Phytoplankton Inland Lakes Wis.*, Part II: 73, Pl. 68, Figs. 18-24. 1924.

Width (with spines) 32 μ , length (with spines) 28 μ . Hidden Lake.

STAURASTRUM DICKIEI Ralfs; Smith, *Phytoplankton Inland Lakes Wis.*, Part II: 76. 1924.

Width 40 μ , length 35.4 μ . Moose Lake. Hidden Lake.

STAURASTRUM DICKIEI var. CIRCULARE Turner; West and West, and Carter, *British Desmidiaceae*, V, Pl. 129, Fig. 16. 1923.

Width 46.8 μ , length 52.6 μ , isthmus 13.6 μ . Moose Lake. New record for Michigan.

STAURASTRUM DICKIEI var. RHOMBOIDEUM W. & G. S. West; West and West, *Journ. Linn. Soc. Bot.*, 35, Pl. 16, Fig. 9. 1903.

Width 54.6 μ , length 39 μ , isthmus 11.7 μ . Hidden Lake. New record for Michigan.

STAUSTRUM FURCIGERUM De Bréb.; Smith, *Phytoplankton Inland Lakes Wis.*, Part II: 122, Pl. 83, Figs. 4-7. 1923.

Width 50 μ , length (including processes) 54 μ , isthmus 11.7 μ . Hidden Lake.

STAUSTRUM GLADIOSUM Turner; West and West, and Carter, *British Desmidiaceae*, V: 57, Pl. 137, Fig. 2. 1924.

Width 48.7 μ , length 44.8 μ , isthmus 17.5 μ . Hidden Lake.

STAUSTRUM GRACILE var. NANUM Wille; West and West, and Carter, *British Desmidiaceae*, V: 100, Pl. 144, Figs. 8-9. 1923. Hidden Lake.

STAUSTRUM MAAMENSE Arch.; Prescott and Magnotta, *Pap. Mich. Acad. Sci., Arts and Letters*, 20 (1934): 163, Pl. 26, Figs. 14-15. 1935.

Width 30.4 μ , length 34.2 μ , isthmus 13.2 μ . Moose Lake.

STAUSTRUM MARGARITACEUM (Ehr.) Menegh. — Borge, *Arkiv f. Bot.*, 19, No. 17: 39, Pl. 1, Fig. 7. 1925.

Width 26.6 μ , length 29.2 μ , isthmus 7.5 μ . I have found 4- and 5-radiate cells which are identical with the form described by Borge. Hidden Lake.

STAUSTRUM MINNESOTENSE Wolle; Smith, *Phytoplankton Inland Lakes Wis.*, Part II: 81, Pl. 71, Figs. 14-15. 1924.

Width (including spines) 169 μ , length (including spines) 144 μ , isthmus 41 μ . Moose Lake. New record for Michigan.

STAUSTRUM OPHIURA var. CAMBRICUM (Lund.) W. & G. S. West; Brown, *Trans. Am. Microsc. Soc.*, 49: 123, Pl. 14, Fig. 82. 1930. Moose Lake. New record for Michigan.

STAUSTRUM PACHYRHYNCHUM Nordstedt; West and West, *British Desmidiaceae*, IV: 151, Pl. 121, Figs. 8-9. 1912.

Width 32 μ , length 35 μ , isthmus 7.8 μ . Moose Lake.

STAUSTRUM SEXCOSTATUM var. PRODUCTUM W. West; West and West, and Carter, *British Desmidiaceae*, V, Pl. 150, Fig. 15. 1923.

Width 41.8 μ , length 44 μ , isthmus 17.5 μ . Mud flat on Passage Island. New record for Michigan.

EUASTRUM AFFINE Ralfs; West and West, *British Desmidiaceae*, II: 17, Pl. 35, Figs. 11-12. 1905.

Width 62.2 μ , length 117 μ , isthmus 19.5 μ . Moose Lake.

EUASTRUM ANSATUM Ralfs; West and West, *British Desmidiaceae*, II: 27, Pl. 36, Figs. 10-13. 1905.

Width 46.8 μ , length 89.7 μ , isthmus 15.6 μ . Moose Lake.

EUASTRUM ATTENUATUM Wolle; West and West, *Trans. Linn. Soc. Bot.*, 5: 243, Pl. 14, Figs. 20–21. 1896.

Width 35 μ , length 59.5 μ , thickness 23.4 μ , isthmus 11.7 μ .
Moose Lake.

EUASTRUM BIDENTATUM Naeg.; West and West, *British Desmidiaceae*, II: 39, Pl. 37, Figs. 16–19. 1905.

Width 35 μ , length 58.5 μ , isthmus 7.8 μ . From green scum on moist soil near trail to Tobin Harbor.

EUASTRUM CRASSANGULATUM Boerg.; West and West, *British Desmidiaceae*, II: 70, Pl. 39, Fig. 17. 1905.

Sargent Lake. Pl. XIX, Fig. 15. New record for Michigan.

EUASTRUM DIDELTA (Turp.) Ralfs; West and West, *British Desmidiaceae*, II: 15, Pl. 35, Figs. 3–7. 1905.

Width 66.3 μ , length 136.5 μ , isthmus 19.5 μ . Hidden Lake.

EUASTRUM DIVARICATUM Lund.; West and West, *British Desmidiaceae*, II: 42, Pl. 38, Figs. 3–4. 1905.

Width 34 μ , length 39 μ , isthmus 6 μ . Moose Lake. New record for Michigan.

EUASTRUM ELEGANS (De Bréb.) Kuetz.; West and West, *British Desmidiaceae*, II: 48, Pl. 38, Figs. 16–21. 1905.

Width 24 μ , length 35 μ , isthmus 7.8 μ . Lake Forbes.

EUASTRUM EVOLUTUM (Nordstedt) W. & G. S. West; West and West, *Trans. Linn. Soc. Bot.*, 5: 243, Pl. 14, Fig. 22. 1896.

Width 40 μ , length 65 μ , isthmus 14 μ . From green scum on damp soil near trail to Tobin Harbor.

EUASTRUM OBLONGUM (Grev.) Ralfs; West and West, *British Desmidiaceae*, II: 12, Pl. 35, Fig. 2. 1905.

Width 66 μ , length 136.5 μ . Moose Lake.

EUASTRUM PECTINATUM De Bréb. var. INEVOLUTUM W. & G. S. West; West and West, *British Desmidiaceae*, II: 61, Pl. 39, Figs. 13–15. 1905.

Width 45.6 μ , length 68.4 μ , isthmus 15.5 μ . In the Isle Royale collections this species shows a sinus which opens outwardly, as in the typical form. The apical lobe is, however, distinctly like that of *inevolutum*. Pl. XIX, Figs. 9–10. Moose Lake. New record for Michigan.

EUASTRUM PINNATUM Ralfs; West and West, *British Desmidiaceae*, II: 10, Pl. 34, Figs. 3–6. 1904.

Width 70 μ , length 135 μ , isthmus 21 μ . Hidden Lake.

EUASTRUM VALIDUM W. & G. S. West; West and West, *British Desmidiaceae*, II: 75, Pl. 40, Figs. 21–22. 1905.

Width 24 μ , length 35.5 μ , isthmus 5.6 μ . Pl. XIX, Fig. 12. Moose Lake. New record for Michigan.

EUASTRUM VERRUCOSUM Ehr.; West and West, *British Desmidiaceae*, II: 64, Pl. 40, Fig. 1. 1904.

Width 81 μ , length 95 μ , isthmus 21.4 μ . Moose Lake. Hidden Lake.

TETMEMORUS LAEVIS (Kuetz.) Ralfs; West and West, *British Desmidiaceae*, I: 222, Pl. 32, Figs. 11–16. 1904.

Width 23.4 μ , length 78 μ . Moose Lake.

MICRASTERIAS APICULATA (Ehr.) Menegh.; West and West, *British Desmidiaceae*, II: 97, Pl. 47, Figs. 1–2. 1905.

Lake Sargent, on stems of submerged grass.

MICRASTERIAS APICULATA var. FIMBRIATA (Ralfs) Nordstedt; West and West, *British Desmidiaceae*, II: 99, Pl. 46, Fig. 6. 1905.

Common in several lakes with a wide pH range. Also from green scum on damp soil.

MICRASTERIAS CONFERTA Lund.; West and West, *British Desmidiaceae*, II: 88, Pl. 43, Figs. 4–8. 1905. Forma.

From green scum on damp soil.

MICRASTERIAS CRUX-MELITENSIS (Ehr.) Hass.; West and West, *British Desmidiaceae*, II: 116, Pl. 53, Figs. 1–3. 1905.

Hidden Lake.

MICRASTERIAS DENTICULATA var. NOTATA Nordstedt; West and West, *British Desmidiaceae*, II: 108, Pl. 50, Fig. 6. 1905.

Width 196 μ , length 229 μ , isthmus 28 μ . Small pool in Sphagnum swamp. New record for Michigan.

MICRASTERIAS LATICEPS Nordstedt; Smith, *Phytoplankton Inland Lakes Wis.*, Part II: 41, Pl. 59, Fig. 3. 1924.

Width 152 μ , length 136.5 μ , isthmus 23.4 μ . Moose Lake. Hidden Lake.

MICRASTERIAS PAPILLIFERA De Bréb.; West and West, *British Desmidiaceae*, II: 91, Pl. 44, Figs. 1–2, 7. 1905.

Width 113.2 μ , length 117 μ , isthmus 23.4 μ . Lake Ritchie. Moose Lake. Hidden Lake.

MICRASTERIAS PINNATIFIDA (Kuetz.) Ralfs; West and West, *British Desmidiaceae*, II: 80, Pl. 41, Figs. 7–11, 13. 1905.

Moose Lake.

MICRASTERIAS RADIATA Hass.; West and West, *British Desmidiaceae*, II: 113, Pl. 52, Figs. 1-9. 1905.

Pool in swamp. Moose Lake.

MICRASTERIAS SOL (Ehr.) Kuetz.; West and West, *British Desmidiaceae*, II: 95, Pl. 46, Figs. 1-2. 1905.

Moose Lake. New record for Michigan.

DESMIDIUM APTOGONIUM De Bréb.; Smith, *Phytoplankton Inland Lakes Wis.*, Part II: 144, Pl. 88, Figs. 3-4. 1924.

Moose Lake.

DESMIDIUM ASYMMETRICUM Grönblad, *Acta Soc. pro Fauna et Flora Fenn.*, 47, Pl. 1, Figs. 5-7. 1920.

Width 27-28 μ , length 15.6-23.4 μ . Pl. XIX, Fig. 17. This is apparently the first record of *asymmetricum* in North America.

DESMIDIUM BAILEYI (Ralfs) Nordstedt; Smith, *Phytoplankton Inland Lakes Wis.*, Part II: 145, Pl. 88, Figs. 5-7. 1924.

Wallace Lake.

DESMIDIUM GREVILLEI (Kuetz.) De Bary; Smith, *Phytoplankton Inland Lakes Wis.*, Part II: 145, Pl. 88, Fig. 8. 1924.

Moose Lake. New record for Michigan.

DESMIDIUM SWARTZII C. A. Agardh; Smith, *Phytoplankton Inland Lakes Wis.*, Part II: 144, Pl. 88, Figs. 1-2. 1924.

Hidden Lake. New record for Michigan.

GYMNOZYGA MONILIFORMIS Ehr.; Smith, *Phytoplankton Inland Lakes Wis.*, Part II: 146, Pl. 87, Fig. 11. 1924.

Generally distributed, appearing in nearly all samples. New record for Michigan.

HYALOTHECA DISSILIENS (Smith) De Bréb.; Smith, *Phytoplankton Inland Lakes Wis.*, Part II: 142, Pl. 87, Figs. 8-9. 1924.

Generally distributed.

HYALOTHECA MUCOSA (Dillwyn) Ehr.; Smith, *Phytoplankton Inland Lakes Wis.*, Part II: 142, Pl. 87, Fig. 10. 1924.

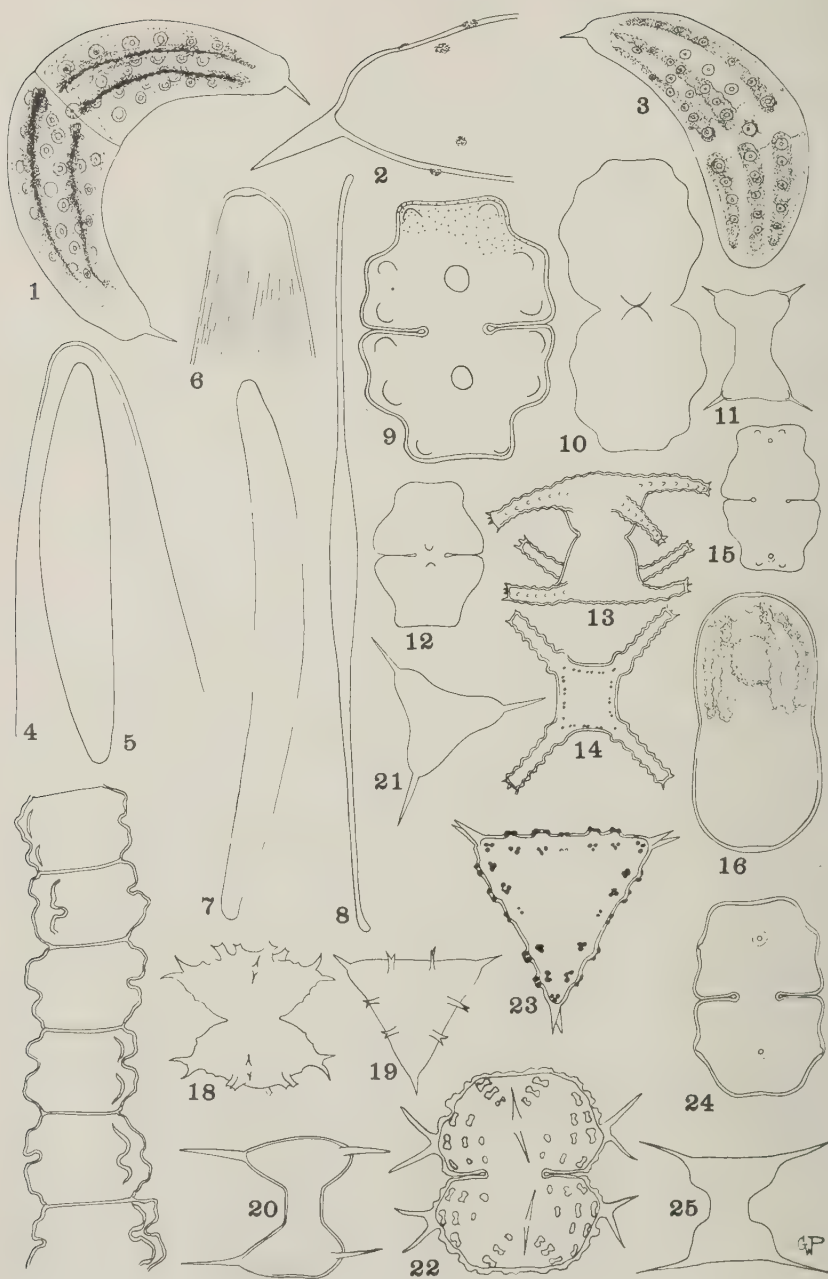
Moose Lake.

ALBION COLLEGE
ALBION, MICHIGAN

LITERATURE

1. BORGE, O. 1925. Die von Dr. F. C. Hoehne während der Expedition Roosevelt-Rondon gesammelten Süßwasseralgen. *Arkiv f. Bot.*, 19 (7) : 1-56, 6 Taf., 3 Textfig.
2. CEDERCREUTZ, CARL. 1932. Süßwasseralgen aus Petsamo II. *Mem. Soc. pro Fauna et Flora Fenn.*, 7 (1930-31) : 236-248, 17 figs.
3. GRÖNBLAD, ROLF. 1920. Finnländische Desmidiaceen aus Keuru. *Acta Soc. pro Fauna et Flora Fenn.*, 47(4) : 1-98, pls. 1-6.
4. ——— 1924. Observations on Some Desmids. *Acta Soc. pro Fauna et Flora Fenn.*, 55(3) : 1-18, 2 pls.
5. HOMFELD, H. 1929. Beitrag zur Kenntnis der Desmidiaceen Nordwestdeutschlands besonders ihrer Zygoten. *Pflanzenforschung*, 12 : 1-96, Taf. 1-9.
6. NICHOLS, GEORGE E., AND ACKLEY, ALMA B. 1932. The Desmids of Michigan, with Special Reference to the Douglas Lake Region. *Pap. Mich. Acad. Sci., Arts and Letters*, 15 (1931) : 113-140.
7. PRESCOTT, GERALD W., AND MAGNOTTA, ANGELINA. 1935. Notes on Michigan Desmids, with Descriptions of Some Species and Varieties New to Science. *Pap. Mich. Acad. Sci., Arts and Letters*, 20 (1934) : 157-170, pls. 25-26.
8. SMITH, GILBERT M. 1924. Phytoplankton of the Inland Lakes of Wisconsin. *Wis. Geol. Nat. Hist. Surv., Bull.* 57, Part II. Madison, Wisconsin.
9. TAYLOR, WM. RANDOLPH. 1934, 1935. The Fresh-Water Algae of Newfoundland. *Pap. Mich. Acad. Sci., Arts and Letters*, 19 (1933) : 217-278, pls. 46-57; 20 (1934) : 185-230, pls. 33-49.
10. WEST, W., AND WEST, G. S. 1896. On Some North American Desmidiaceae. *Trans. Linn. Soc. London (Botany)*, 5(5) : 229-274, pls. 12-18.
11. ——— 1904-12. A Monograph of the British Desmidiaceae. Vols. I-IV Ray Society, London.
12. ——— AND CARTER, NELLIE. 1923. *Ibid.* Vol. V:

PLATE XIX



EXPLANATION OF PLATE XIX

- FIGS. 1-3. *Closterioides spinosus*, gen. et sp. nov.
FIGS. 4-5. *Closterium Lunula* f. *minor* W. & G. S. West
FIGS. 6-7. *Closterium turgidum* Ehr.
FIG. 8. *Closterium setaceum* Ehr.
FIGS. 9-10. *Euastrum pectinatum* De Bréb. var. *inevolutum* W. & G. S. West
FIG. 11. *Arthrodesmus triangularis* Lag., var.
FIG. 12. *Euastrum validum* W. & G. S. West
FIGS. 13-14. *Staurastrum arachne* Ralfs., var.
FIG. 15. *Euastrum crassangulatum* Boerg.
FIG. 16. *Cylindrocystis diplospora* Lund.
FIG. 17. *Desmidium asymmetricum* Grönblad
FIGS. 18-19. *Staurastrum arcuatum* Nordstedt
FIGS. 20-21. *Staurastrum cuspidatum* De Bréb.
FIGS. 22-23. *Staurastrum cornutum* Archer
FIG. 24. *Cosmarium venustum* var. *excavatum* (Eickl. & Gutw.) W. West
FIG. 25. *Arthrodesmus Incus* var. *extensus* Anders.

UNUSUAL AGARICS FROM MICHIGAN. IV *

ALEXANDER H. SMITH

DURING the collecting season of 1935 abundant rains in the last part of June, the last of July, and the first two weeks in August caused a luxuriant development of a summer agaric flora. As a result, species which have not been found in the vicinity of Ann Arbor for many years were collected in abundance. *Lactarius indigo* Schw., *Amanita cothurnata* Atk., *Amanita peckiana* Kauff., and *Lepiota floralis* (Berk. & Rav.) Sacc. are four notable examples. Certain species were found on the ordinarily very dry and barren sandy hillsides. In this respect the occurrence of *Lepiota floralis* was particularly interesting. It covered an otherwise barren sandy slope in the George Reserve near Pinckney and, in spite of diligent search, it was not located in any other place during the season. *Amanita peckiana*, which Kauffman (4) reported as occurring on sandy ground under white pine, was found abundantly on semibarren sandy soil along the borders of oak groves in the George Reserve and in several other locations near Pinckney and Chelsea.

Certain species collected previous to 1935 have also been identified and are here reported. A total of twenty species are discussed. Sixteen have apparently not been reported previously from Michigan. The collection numbers and the photographs are those of the writer unless otherwise stated.

LIST OF SPECIES

COLLYBIA TESQUORUM Fr. *sensu* Bresadola (Pl. XXIII, Fig. b).

— Gregarious on the ground in a grassy open woods, Whitmore Lake, June 22, 1935 (1393); George Reserve, Pinckney, August 10, 1935 (1775). The colors were "Prout's brown"¹ to "warm sepia" or, occasionally, nearly "auburn," often "clay color" to "buck-

* Papers from the Department of Botany and the Herbarium of the University of Michigan, No. 567.

¹ All names of colors within quotation marks are taken from R. Ridgway, *Color Standards and Color Nomenclature*. 1912.

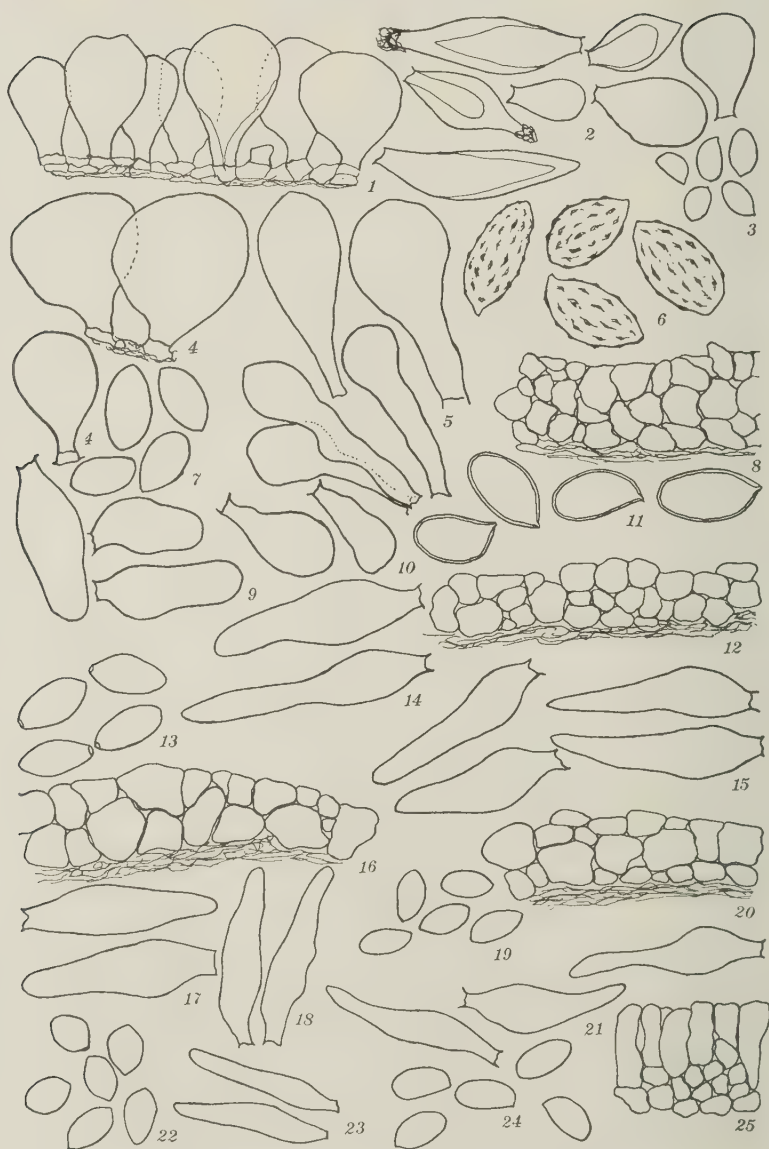


FIG. 7. For explanation of figures see bottom of opposite page

thorn brown" on the disk. In age the pilei faded to "vinaceous buff" or "avellaneous." As in many of the hygrophanous species in this genus, the dark gills might at first lead one to look among the dark-spored genera when trying to identify a collection. The spores measure $6-7 \times 3.5-4 \mu$, are smooth, hyaline, and ellipsoid. The odor and taste are slightly farinaceous when the flesh is crushed; cystidia are not differentiated; and the pileus trama is homogeneous.

DECONICA RHOMBOIDOSPORA Atk. (text Fig. 7, Nos. 22-23).—Scattered on sticks in a burnt-over area, Lakeland, June 11, 1935 (1320); on sticks and débris, Dexter, June 17, 1935 (1350); cespitose to densely gregarious on chips and débris near an old woodpile, Ann Arbor, June 19, 1935 (1378). When fresh the pilei are "russet" to "Mars brown" or with a sordid purplish tinge, but soon fade to "pale ochraceous buff" or a paler grayish buff. The stipe is "Mars brown" or darker, and the gills are close to "cinnamon-brown." The colors as described by Atkin-

EXPLANATION OF FIGURE 7

- Deconica rhomboidospora* Atk. Nos. 22, 23. No. 22, spores, $\times 850$. No. 23, cystidia from the gill edge, $\times 450$
- Naucoria hamadryas* Fr. Nos. 5, 6, 8. No. 5, five sterile cells from the gill edge, $\times 450$. No. 6, spores, $\times 850$. No. 8, section showing the inflated cells which form the cuticle of the pileus, $\times 150$
- Psathyra bipellis* Quéf. Nos. 10, 11, 12, 14. No. 10, saccate cells from the gill edge, $\times 450$. No. 11, spores, $\times 850$. No. 12, inflated cells forming the cuticle of the pileus, $\times 157$. No. 14, cystidia, $\times 450$
- Psathyra gossypina* Fr. Nos. 13, 16, 17, 18. No. 13, spores, $\times 850$. No. 16, inflated cells forming the cuticle of the pileus, $\times 157$. No. 17, cystidia from sides of the gills, $\times 450$. No. 18, cystidia from the gill edge, $\times 450$
- Psathyra multipedata* Pk. Nos. 21, 24, 25. No. 21, three cystidia from the side and edge of the gills, $\times 450$. No. 24, spores, $\times 850$. No. 25, inflated cells from the cuticle of the pileus, $\times 157$
- Psathyra pennata* Fr. Nos. 15, 19, 20. No. 15, cystidia, $\times 450$. No. 19, spores, $\times 850$. No. 20, inflated cells forming the cuticle of the pileus, $\times 157$
- Psathyra Typhae* Kalch. Nos. 4, 7, 9. No. 4, pedicellate cells from the cuticle of the pileus, $\times 450$. No. 7, spores, $\times 850$. No. 9, cystidia from the sides and edges of the lamellae, $\times 450$
- Psilocybe camptopoda* Pk. Nos. 1, 2, 3. No. 1, pedicellate cells from the cuticle of the pileus, $\times 450$. No. 2, four thick-walled cystidia from the sides of the gills and three saccate cells from the gill edge, all $\times 450$. No. 3, spores, $\times 850$

son are those of faded pilei in the writer's collections. The brown gills remind one of the genus *Tubaria*, but the spores are dark purplish brown in mass. Cystidia are scattered on and near the gill edges and measure $30-40 \times 7-11 \mu$. The pileus trama is homogeneous.

HYGROPHORUS DISCOIDEUS Fr. — Scattered on moss and humus under spruce, cedar, and aspen, Rees' Bog, Burt Lake (1109, 1134, 1160, 1247), and in Mud Lake Bog, Cheboygan Co., Oct. 9-16, 1934. The basidia were four-spored and the spores measure $5-6 \times 4 \mu$. The stems were white, never "gilvo-furfuraceous," as described by Bresadola (2).

LEPIOTA FLORALIS (Berk. & Rav.) Sacc. (Pl. XXII, Fig. a). — Very abundant on a sandy hillside, George Reserve, Pinckney, Aug. 10, 1935 (1776). Murrill (7) reports it as known from New Jersey and North and South Carolina.

MARASMIUS IMPUDICUS Fr. (Pl. XXI, Fig. b). — On needle beds in a spruce plantation, Aug. 3 (1698), and Aug. 7, 1935 (1744). Found in great abundance after warm rains in early August.

NAUCORIA CARPOPHILA Fr. — On old leaves and débris in wet woods of maple, beech, and hemlock, Silver Creek, Emerson, Sept. 2, 1933 (33-849).

NAUCORIA CIDARIS var. *MINOR* Fr. (Pl. XXIII, Fig. c). — Pileus 10-25 mm. broad, convex or plane to campanulate, glabrous, lubricous, hygrophanous, margin faintly striatulate when moist, "Sudan brown" on the disk, "raw sienna" on the margin, fading to "pale orange-yellow"; lamellae close, narrow to moderately broad, narrowly adnexed, becoming sinuate, seceding, pallid olivaceous gray, becoming "old gold," edge minutely eroded; stipe 2-4 cm. $\times$ 1.5-2 mm., horny, glabrous, lubricous, reddish brown to blackish at base, becoming "Sudan brown," "antique brown," or paler above; spores $5-6 \times 3 \mu$, smooth, very pale under the microscope; basidia $30-32 \times 4-5 \mu$, four-spored, the sterigmata small and inconspicuous; cystidia very rare on the sides, abundant on the edge of the gills, fusoid-ventricose to filamentous, $25-35 \times 7-11 \mu$; gill trama homogeneous, threads parallel to subparallel, the cells short and moderately inflated; pileus trama with a layer of enlarged parenchymatous cells over the surface, remainder of compact smaller hyphae; odor and taste not distinctive.

On wet ground under sedges, Silver Creek, Emerson, Sept. 2, 1933 (33-850; 33-857); on old débris, Huron Mts., Big Bay, Sept. 16, 1933 (33-994). The dark brown horny stipe reminds one of that of *Omphalia campanella* Fr. Fries' (3) illustration (Pl. 123, Fig. 2) of *N. cidaris* var. *minor* pictures the writer's collections well.

NAUCORIA HAMADRYAS Fr. (text Fig. 7, Nos. 5, 6, 8). — On débris in Mud Lake Bog, Whitmore Lake, Aug. 24, 1929, and Oct. 8, 1933 (33-1106). The large ($14-18 \times 7-9 \mu$) rough spores and the cystidia on the gill edge distinguish it microscopically. The surface of the pileus is covered by a region of inflated cells having dark brown walls.

NOLANEA VERSATILIS Fr. (Pl. XXIV, Fig. a). — Gregarious on muck in low swampy areas, Huron Mts., Big Bay, Sept. 16, 1933 (33-986), and Pinckney, Oct. 1, 1933 (33-1050). The spores measure $10-12 \times 6-7 \mu$ and $10-14 \times 6-8 \mu$.

PLUTEUS PHLEBOPHORUS Fr. var. *ALBO-FARINOSUS* Rea (Pl. XXIII, Fig. a). — Singly around oak stumps, Ann Arbor, July 2, 1935 (1458).

PSATHYRA BIPELLIS Quél. (Pl. XXIV, Fig. b; text Fig. 7, Nos. 10, 11, 12, 14). — Pileus 1-3 cm. broad, obtusely conic, becoming somewhat expanded, often with an obtuse umbo, "diamine brown" when young and fresh, sometimes becoming "Mars brown" before fading, hygrophane, fading to "light grayish vinaceous," at first with scattered fibrils over the surface and a fibrillose zone near the margin from the broken veil, glabrous in age, margin appressed against the stem at first; flesh reddish, very fragile, taste not distinctive, odor faintly fragrant; lamellae moderately close to subdistant, broad, adnate or narrowed at the point of attachment, near "Corinthian pink" at first, becoming dark brown with a persistent reddish tinge, edge minutely white-fimbriate; stipe 1-4 cm. $\times$ 2-3 mm., pallid with a reddish to pinkish tinge, very fragile, at first covered by a fibrillose-canescenscent layer part way to apex, with scattered fibrillose points above, becoming nearly glabrous in age; spores $12-16 \times 6-8 \mu$, very dark purplish brown under the microscope, smooth; cystidia on sides and edges, $50-70 \times 10-16 \mu$, fusoid-ventricose, smooth; pileus trama corticated by an area of inflated cells arranged irregularly.

Scattered on freshly spaded sandy soil along a road in an open oak woods, Ann Arbor, June 21, 1935 (1389).

PSATHYRA GOSSYPINA Fr. (Pl. XXII, Fig. c; text Fig. 7, Nos. 13, 16, 17, 18). — On soil at the edge of a pine plantation, Ann Arbor, Aug. 7, 1935 (1743). In this collection the universal veil is exceptionally well developed and slightly buff-colored. The spores measure $8-10 \times 4-5 \mu$; the cystidia, $35-45 \times 8-12 \mu$. The pileus surface is covered by a region of globular inflated cells.

PSATHYRA MICROSPERMA Pk. (Pl. XX). — Densely cespitose on débris in a low grassy woods, Stockbridge, Oct. 10, 1933 (33-1116). The spores measure $6-7.5(8) \times 4 \mu$; the cystidia, $30-35 \times 8-11 \mu$. The pileus trama is corticated by a region of enlarged cells.

PSATHYRA MULTIPEDATA Pk. (Pl. XXI, Fig. a; text Fig. 7, Nos. 21, 24, 25). — Densely cespitose on humus in an open oak woods, Lakeland, Sept. 28, 1933 (33-1033). The microscopic characters of this species are identical with those of *P. microsperma*. The rugulose margin of the pileus of *P. multipedata*, the umbo which remains moist after the margin has faded, and the faint fibrillose zone near the base of the stem distinguish it from *P. microsperma*.

PSATHYRA PENNATA Fr. (Pl. XXIII, Fig. d; text Fig. 7, Nos. 15, 19, 20). — Scattered to gregarious on burnt-over ground, Lakeland, June 24, 1935 (1405). The spores measure $6-8 \times 3.5-4 \mu$; the cystidia, $40-50 \times 10-12 \mu$. Cystidia are present on the sides and edges of the gills, and the pileus trama is corticated by an area of irregularly arranged inflated cells.

PSATHYRA TYPHAE Kalch. (text Fig. 7, Nos. 4, 7, 9). — Pileus 5-20 mm. broad, convex, becoming nearly plane, at first covered with scanty patches of pale tan fibrils, soon glabrous, "russet" to "cinnamon-brown" or "Sayal brown," hygrophanous, fading to pale buff, pellucid-striate when moist, somewhat plicate when faded; flesh very fragile, thin and watery; lamellae subdistant to moderately close, broad, attached by a narrow tooth or nearly free, pallid to whitish at first, soon pale brown, with finally a tinge of purplish brown; stipe 1-2 cm. $\times$ 1-1.5 mm., hyaline-white, very weak, watery, and fragile, covered by scattered fibrils or with a denser fibrillose zone toward the base, base slightly enlarged and delicately mycelioid at the point of attachment; spores $10-12 \times 5-6.5 \mu$, pale purplish brown under the microscope; cystidia on gill edge only, $30-45 \times 7-12 \mu$, smooth,

cylindric, and obtuse to broadly fusoid-ventricose; basidia four-spored; pileus trama with layer of loosely arranged clavate pedicellate cells over the surface.

On dead stems of *Typha latifolia* L., Mud Lake Bog, Washenaw Co., July 9, 1935 (1498). Both Boudier (1) and Møller (6) accurately describe and illustrate the species. The russet brown color of the pileus, the fibrillose ring near the middle of the stem, and the soft fragile consistency are constant characters. *Naucoria scirpicola* Pk. (*Ann. Rep. New York State Mus.*, 42: 19-20. 1889) is very likely this species. The spores of the type are identical in size and shape with those of *P. Typhae* and, in addition, possess the characteristic smoky tinge under the microscope. The structure of the pileus and the nature and distribution of the cystidia could not be determined from the type specimens of *N. scirpicola*. The russet-brown pileus and the gills, which remain cinnamon-brown for a long time, lead one to believe that the fungus belongs among the ocher-spored species.

PSILOCYBE CAMPTOPODA (Pk.) Sacc. (text Fig. 7, Nos. 1, 2, 3). —

Pileus 1-2.5 (3) cm. broad, broadly convex, becoming plane, varying from near "buckthorn brown" to "cinnamon" on the disk when fresh, often "pale ochraceous buff" on the margin, hygrophanous, whitish when dry, when water-soaked the colors dull and grayish brown, putty color, or near "avellaneous," closely striate when moist, glabrous, margin inrolled at first, flesh moderately thick on the disk in large specimens, thin toward the margin, rather pliant; lamellae narrow (2-3 mm.), adnate, often seceding, crowded, whitish, becoming pinkish brown; stipe short, 1-2 cm. $\times$ 2-3 mm., curved, pale grayish brown, coarsely pruinose, glabrous in age, hollow, cartilaginous, base white-strigose; odor and taste none or slight; spores 6-7 $\times$ 3.5-4 μ , very pale reddish brown under the microscope, dull reddish brown with a purplish tinge in mass; basidia four-spored, 20-22 $\times$ 4-5 μ ; cystidia on the sides of the gills numerous, 35-40 $\times$ 9-12 μ , more or less incrusting over the apex, thick-walled; cystidia on the gill edge sacklike, 30-40 $\times$ 15-20 μ , not incrusting, thin-walled; pileus trama corticated by a layer of globose-pedicellate cells.

Densely gregarious to scattered on decaying logs in an elm swamp, Stockbridge, Oct. 10, 1933 (33-1117); Fowlerville, Oct. 21, 1933 (33-1131), and Stockbridge, July 5, 1935 (1488).

This is a decidedly top-heavy agaric when well developed. The *Naucoria*-like habit and the pale reddish gills are deceiving, but the spore color in mass is typical of *Psilocybe*. The cystidia are similar to those of *Psilocybe sarcocephala* Fr. There are no traces of a fibrillose veil on even the youngest fruiting bodies. The pruinosity of the stem and pileus margin is rather coarse. It is clear from the studies of *Psathyra Typhae* and *Psilocybe camptopoda* that anatomical studies of these fragile purple-brown-spored species will be as valuable as they have been shown to be in the parallel ocher-brown-spored series. *P. camptopoda* was apparently first collected in Michigan on Nov. 8, 1893, by Conrad and Langdon and determined by Peck. Kauffman obtained it Oct. 19, 1913, but did not determine the collection.

PSILOCYBE SQUALIDELLA var. *MACROSPORA* Pk. (Pl. XXII, Fig. b). —

A very common agaric in sphagnum bogs and on wet exposed peat.

TRICHOLOMA FLAVOBRUNNEUM Fr. — This species has been collected at Magnetawan, Ontario, Canada (H. C. Beardslee, Sept. 2, 1931), but apparently has not been previously reported from Michigan. The writer found it at Wilderness State Park, Emmet Co., Oct. 12, 1934 (1145), where it was fairly abundant under a mixed stand of red pine and aspen.

TRICHOLOMA PERSICOLOR Fr. *sensu* Ricken. — Pileus 2-4 cm. broad, broadly convex, flat or disk depressed at maturity, margin inrolled and faintly striatulate when fresh and moist, in age often undulate and contorted, glabrous, subhygrophanous, "Etruscan red," fading to "flesh pink," "seashell pink," or white with a tinge of pink along the margin, in age the disk often bister or sordid brownish; flesh moderately thick, exceedingly brittle; lamellae crowded, narrow, white, slightly sinuate to adnate, intervenose; stipe 1-3 cm. $\times$ 3-8 mm., strongly enlarged above, narrow to pointed at the base, often compressed, hollow, concolorous with pileus or whitish and covered by a pink pruinosity; spores $4-5 \times 2 \mu$; basidia four-spored, cystidia not differentiated.

Gregarious to subcespitate on needle beds under spruce in a plantation at Ann Arbor, Aug. 7, 1935 (1748).

UNIVERSITY OF MICHIGAN

LITERATURE CITED

1. BOUDIER, E. 1897. Nouvelles espèces ou variétés de champignons de France. Bulletin de la Société mycologique de France, 13 : 11-18.
2. BRESADOLA, J. 1928. Iconographia Mycologica, Vol. VII.
3. FRIES, ELIAS MAGNUS. 1877. Icones Selectae Hymenomycetum, Vol. II. Upsala.
4. KAUFFMAN, C. H. 1918. The Agaricaceae of Michigan. Lansing, Michigan.
5. KÜHNER, ROBERT. 1935. Le Genre Galera (Fries) Quélet. Encyclopédie mycologique, Vol. VII. Paris.
6. MØLLER, F. H. 1933. *Psathyra Typhae* (Kalch.) Fr. Dunhammer-Stribehat. Friesia, 1 : 84-87.
7. MURRILL, W. A. 1914. North American Flora, Vol. 10, Part I.
8. REA, CARLETON. 1922. British Basidiomycetae. Cambridge.
9. RICKEN, A. 1915. Die Blätterpilze Deutschlands. Leipzig.

•

PLATES XX-XXIV



Psathyra microsperma Pk., $\times 1$

PLATE XXI



FIG. a. *Psathyra multipedata* Pk., $\times 1$

FIG. b. *Marasmius impudicus* Fr., $\times 1$

PLATE XXII



FIG. a. *Lepiota floralis* (Berk. & Rav.) Sacc., $\times 1$

FIG. b. *Psilocybe squalidella* var. *macrospora* Pk., $\times 1$

FIG. c. *Psathyra gossypina* Fr., $\times 1$



FIG. a. *Pluteus phlebophorus* var. *albo-farinus* Rea, $\times 1$

FIG. b. *Collybia tesquorum* Fr., $\times 1$

FIG. c. *Naucoria cidaris* var. *minor* Fr., $\times 1$

FIG. d. *Psathyra pennata* Fr., $\times 1$

PLATE XXIV



FIG. a. *Nolanea versatilis* Fr., $\times 1$

FIG. b. *Psathyra bipellis* Quél., $\times 1$

NOTES ON NORTH ATLANTIC MARINE ALGAE. I *

WM. RANDOLPH TAYLOR

IT HAS long been evident that the state of our knowledge of the marine algae of the east coast is entirely unsatisfactory. The basis of all our accounts of American marine algae is W. H. Harvey's *Nereis Boreali-Americana*, essentially the result of a few months' visit to this country on a lecture tour. This work was not represented as a complete account of American marine algae, and indeed was very far from putting our knowledge of the American east coast flora on a level with that of Europe. W. G. Farlow's *Marine Algae of New England*, which appeared about thirty years later, while more comprehensively framed, did not enable the general botanist to identify correctly the majority of the elements in any local flora. F. S. Collins, after thirty years more, helped matters considerably by the *Green Algae of North America*, but since the northeast coast marine algae are in smallest part Chlorophyceae the appearance of his projected account of the marine algae of New England was awaited with interest. His death before it was completed halted all progress to the present along this line.

Meanwhile, continuing interest in marine algae manifested itself in a number of local floral lists, two or three substantial ecological studies, and several important morphological and cytological papers. These studies were apparently hampered and their value was lessened by unfamiliarity with the revisions which European students had found necessary in the nomenclature of these plants and by the lack of any comprehensive account and delimitation of the American species.

* Papers from the Department of Botany and the Herbarium of the University of Michigan, No. 559.

The writer is greatly indebted to the former director, Dr. Elmer D. Merrill, and the curator of algae and present director, Dr. Marshall A. Howe, for the use of Mr. F. S. Collins' manuscript on New England marine algae. Dr. Howe has given valuable advice regarding many technical problems in this study, as has Professor H. H. Bartlett in preparing the descriptions.

An attempt to compile a modern catalogue has brought forcibly to the attention of the writer the fact that many of the names currently applied to the algae of this area have long since been shown to be subject to replacement by others on the score of priority or of wrong generic assignment; those that have received general acceptance abroad will for the most part have to be taken up. The organization of the larger groups has in turn been profoundly changed by the life-history studies of the last twenty-five years. A catalogue assembled today would not closely follow the works of Harvey or Farlow, the Collins list of 1900, or even his manuscript of 1920.

In considering the revisions in nomenclature necessary to put our New England marine algal catalogue in line with current practice we may pass by changes already established, but should note certain new combinations which do not appear to have been made. A number of these were projected in Collins' manuscript and must be accredited to him.

The specimen issued as *Phycologia Boreali-Americana* 477 under the name *Vaucheria piloboloides* var. *compacta* Collins (1900, p. 45) appeared to him ultimately to be unrelated to that species, so that he offered it as an independent type under the name **V. compacta** (Collins) Collins, comb. nov. The antheridia and the oögonia are scattered, whereas in *V. piloboloides* the sexes are grouped together.

Specimens in the genus *Dictyosiphon* are particularly hard at times to segregate. It seems appropriate to follow the Collins manuscript and to reduce *D. hispidus* Kjellm. to varietal status under *D. foeniculaceus* (Huds.) Grev. as var. **hispidus** (Kjellm.) Collins, comb. nov.

Harvey (1853, p. 185) had a robust form of his *Chylocladia Baileyana* as var. *valida*, with stout ultimate branches tapering equally to the ends. The Collins manuscript, using the genus *Lomentaria* and this variety, makes necessary *Lomentaria Baileyana* var. **valida** (Harv.) Collins, comb. nov.

A New England alga has been known as *Lomentaria rosea* since Harvey's time. It should be compared with *Chrysomenia orcadensis* Harv. (1849, p. 100), which he himself later pictured as *C. rosea* var. *orcadensis* (1851, pl. 301.) The American plant is like that figured as *C. rosea* (1851, pl. 358). However, publication of *C. rosea* in the *Nereis Boreali-Americana* did not occur until after the British plates had appeared (1853, p. 186). It will therefore not

do to reduce the Orkney plant to varietal status; undoubtedly close to the plant called *C. rosea* and probably only an exceptionally broad individual, it must represent the type of the species, and the comb. nov. **Lomentaria orcadensis** (Harv.) Collins will be needed, even though the name *C. rosea* did exist in manuscript first ("Memoirs of Dr. Harvey," pp. 217-219. 1869).

To quote from the Collins manuscript, "The examination of an authentic specimen of *Polysiphonia violacea* var. *flexicaulis* collected at Halifax N. S., shows it to be identical with the plant of the Maine coast here described. It is more slender than *P. violacea*, without definite pyramidal outline, the branching more uniform throughout, neither wanting at the base of a branch nor dense and fasciculate at the tip. Technically, the occurrence of a branch in the place of a leaf, not as a development of a leaf, distinguishes it from all our other species of the same habit. . . ." This means that the branch initials replace trichoblasts on certain segments instead of arising in their axils, and it means that the var. *flexicaulis* is not related to *P. violacea*, the structure of which has been described by Falkenberg and others. In manuscript there is proposed the name **P. flexicaulis** (Harv.) Collins, comb. nov., for *P. violacea* var. *flexicaulis* Harv. (1853, p. 44).

The intergrades frequently noticed between *Polysiphonia Harveyi* Bailey and the plant known as *P. Olneyi* Harvey induced Collins in manuscript to reduce the latter to varietal status as *P. Harveyi* var. **Olneyi** (Harv.) Collins, comb. nov.; this change seems advisable, since the var. *Olneyi* is about as different in one direction from *P. Harveyi* as is the var. *arietina* (Bail.) Harv. in the other as a seasonal phase.

In the difficultly separable species of the genus *Rhodomela*, the Collins manuscript decided that *R. Rochei* Harvey (1853, p. 27) was not distinct enough to justify separate status, and offered the name *R. subfusca* (Woodw.) C. Agardh f. **Rochei** (Harv.) Collins, comb. nov.

Other names which Collins had intended to use do not seem to the writer to be needed. He does, however, suggest certain names which appear to have become necessary.

Chaetomorpha atrovirens, sp. nov. — Planta plerumque cum speciebus aliis majoribus laxè intricata; filamentis curvatis, tortuosis, intricatis; cellulis vix vel haud inflatis, media parte 300 vel

380 μ diametentibus, longitudine duplo vel quintuplo (plerumque triplo) longioribus quam latoribus, atroviridibus. Specimen typicum legit cl. Collins ad Revere Beach, Mass., Phyc. Bor.-Am. n. 412, in Herb. Univ. Mich.

Chaetomorpha atrovirens is the name offered for a well-known plant forming loosely entangled mats, usually anchored among other and coarser algae; filaments curved, twisted, interwoven; cells not at all or but slightly swollen, diameter at the middle of the cells 300–380 μ ; cells usually 3 diameters long, but varying from 1.5 to 5.0 diameters, color usually rather dark green. This plant ranges from Connecticut northward to Newfoundland and was issued as Phyc. Bor.-Am. 412. It has been widely interpreted as a later phase in the growth of *C. melagonium*, and by some called *C. Picquotiana*. However, the writer has seen no convincing demonstration of its relation with *C. melagonium*, and the apparent absence of this phase (if it is such) on the west coast is some additional justification for considering it specifically distinct. Objections to identification with *C. Picquotiana* are given by Setchell and Gardner (1920, p. 202): that plant appears to have the same descriptive characters as *C. melagonium*. These writers do not, however, give any correct name for the New England entangled plant; the name *C. melagonium* f. *typica* Kjellm. used for it by Collins (1909, p. 324) obviously cannot be adapted, and consequently in the apparent absence of any legitimate name the new one is presented.

The microscopic creeping and disklike Phacophyceae are particularly difficult problems taxonomically, since at least some of them are likely to prove to be gametophytes of larger plants known only in the sporophytic phases. Until such connection is culturally established many of them will continue to be classified as independent entities. A number of morphologically distinct types are under investigation as possibly worthy of recognition, and one of them has proved abundant enough and sufficiently readily recognized to encourage immediate presentation:

Ascocyclus distromaticus, sp. nov. — Planta fusca, epiphytica discoidea maturitate distromatica ex filamentis ramosis valde separabilibus constans; filamentis patentibus primum uniseriatis, saepe piliferis, demum plerumque divisione horizontali stromata dua formantibus; filamentis vegetativis erectis obtusis fere cylindricis saepissime 3–5-cellulis, 7.7–10.0 μ diametentibus; paraphysibus sessilibus

vel in stipitem unicellulum sedentibus, juvenilibus ovatis, brunneis, aetate parietibus incrassatis, hyalinis, subcylindricis vel paululum angustatis, 7.5–10.0 μ diam., 70–100 μ longis; gametangiis sessilibus vel stipitatis, obtusis, subcylindricis, 7–10 μ diam., 17–56 μ longis, stipitibus unicellulis.

Plant forming epiphytic disks of readily separated branched filaments; spreading filaments 7.0–8.5 μ diam., the cells 1–2 diam. long, at first and sporadically remaining uniseriate, but generally dividing more or less irregularly in the plant of the support, so that the disk is in most part distromatic; erect vegetative filaments blunt on the ends, cylindrical or slightly contracted at the septa, 3–5 (–10) cells long, the cells 7.7–10.0 μ diam., 7.0–14.0 μ long; long colorless hairs frequent, attached to the basal layer, 5.5–9.5 μ diam., the upper cells up to 120 μ long; paraphyses sessile or on one-celled stalks, at first obovate and brown, about 15 μ diam. and 30 μ long, becoming thick-walled and hyaline, subcylindrical or a little tapering, 7.5–10.0 μ diam., 70–100 μ long; plurilocular gametangia generally sessile or on one-celled stalks, sometimes on stalks of 2–3 cells, subcylindrical, obtuse, 7–10 μ diam., 17–56 μ long. Type locality Penikese Island, southern Massachusetts; epiphytic on *Rhodymenia palmata*, July 24, 1923; specimen in Herb. Univ. Mich. The plant is actually quite frequent on this host in the latter part of the summer about the entrances to Buzzards Bay, and fruits at this time of year.

It appears to the writer that the plant described by Farlow as *Myriactis pulvinata* Kütz. var. *minor* Farlow (1881, p. 81) and issued as *Elachistea minor* (Farlow) Collins in Phyc. Bor.-Am. 1592 cannot be retained in either *Myriactis* or *Elachistea*. In examining a great deal of material Dr. Chin-Chih Jao and the writer confirmed the presence of colorless hairs with basal growth and of plurilocular gametangia upon the assimilators. The proper place for this plant appears to be the genus *Myriactula*, established by O. Kuntze (1898) to replace *Myriactis* Kütz., and the name ***Myriactula minor*** (Farlow), comb. nov., is needed.

Farlow (1881, p. 62) records *Phyllitis Fascia* (C. Ag.) Kütz. and var. *caespitosa* from New England. However, this genus name is preëmpted for a genus of ferns. The other frequently used name, *Ilea* Fries, 1825, was based on Entermorphae. This species was associated with *Petalonia* Derbés and Solier as *P. Fascia* (O. F.

Müller) Kuntze, but this author did not make the combinations for the types which appear to be varieties of this plant. To bring them in line the writer would offer *Petalonia Fascia* var. **caespitosa** (J. Agardh), comb. nov., for *Laminaria caespitosa* J. Agardh and *P. Fascia* var. **zosterifolia** (Reinke), comb. nov., for *Phyllitis zosterifolia* Reinke (see Collins, 1909, p. 206; Howe, 1914, p. 50; Setchell and Gardner, 1920, p. 233, 1925, p. 535).

The New England Desmarestiae are not sufficiently variable to give much cause for confusion when allowance is made for the differences between the piliferous early spring state and the denuded state of summer. Hence it was some time before the plant to be described here was associated with *D. aculeata* (L.) Lamour. However, not only was the connection eventually clearly established, but sufficiently lax forms of that species were recognized to render it inadvisable to grant the new plant more than varietal status: *Desmarestia aculeata* var. **attenuata**, var. nov. — Planta multo attenuatior quam typica forma, elongata usque ad 80 cm. vel plus, angustissima ramosa sparsis, ultimis indeterminatis ramulis tenuissimis, usque ad 3-7 cm. longis, determinatis ramulis spinuliformis plerumque absentibus. Tab. XXV, Fig. 1.

Plant much more attenuate than the typical form, elongate, reaching 80 cm. or more, very slender, sparsely branched, the ultimate indeterminate branchlets very delicate, up to 3-7 cm. long, spinuliform determinate branchlets being practically absent. Type locality Penikese Island, southern Massachusetts, where the plants were washed ashore in the sterile summer condition and collected by C.-C. Jao on July 10, 1934; specimen in herb. W. R. Taylor. The variety has also been dredged off Gay Head, Martha's Vineyard, Mass., July 16, 1934, and collected when washed ashore in some abundance on Penikese Island, July 17, 1935, by the writer.

With *Gracilaria multipartita* there has been associated the var. *angustissima* Harv. (1853, p. 107) as a slender plant in the American flora. With the establishment of *G. foliifera* as the proper name for the species the varietal name must be changed if retained. It seems to the writer that, in spite of the wide variation in the species, there is need for a designation of the barely compressed forms previously called by the varietal name and that the combination *Gracilaria foliifera* (Forssk.) Borg. var. **angustissima** (Harv.), comb. nov., should be made.

The *Delesseria denticulata* of Phyc. Bor.-Am. 995 has been shifted to the genus *Membranoptera* as *M. denticulata* (Mont.) Kylin; if the var. *angustifolia* Lyngbye is to be recognized, it will apparently have to be transferred as *M. denticulata* var. *angustifolia* (Lyngb.), comb. nov.

The common rhodophycean *Lomentaria Baileyana*, in the southern Massachusetts area, generally has slender, subcylindrical, curved branches. In New England there occurs a plant which may be described as follows: *Lomentaria Baileyana* (Harv.) Farlow var. *siliquiformis*, var. nov. — Planta parva, saepe densior et colore levior quam in forma typica; ultimis ramulis plerumque loco unilateralibus, frequenter bilateralibus vel irregularibus, basi acute constrictis, superne attenuatis ex diametro 2-3 mm. usque ad subacutos apices in tota longitudine 1-2 cm.

Plants small, often denser than in the type, rather more brightly colored; ultimate branchlets usually unilaterally placed, sometimes bilateral or irregular, bases sharply contracted, above which point they taper from a diameter of 2-3 mm. to the subacute apices in a total length of 1-2 cm. Type locality Black Rock, New Bedford Harbor, southern Massachusetts, where the plants were growing attached in tide pools; specimen in herb. W. R. Taylor. Collected by H. T. Croasdale July 28, 1931.

It seems quite certain that the plant which has passed under the name *Polysiphonia violacea* as derived from the New England coast and northward is not that species. So far as the writer is familiar with present-day practice, two forms were currently called by this name: one rather pyramidal and densely bushy; the other much taller, with angled main axes and almost slippery consistency. It is the latter which has figured in experimental and cytological studies conducted in our area and which has gone into the trade for sale as teaching material. There seems no doubt but that it should be called *P. flexicaulis*, for reasons given above. The other form is much scarcer, and its stations are not sufficiently easily reached to render it suitable material for experimental studies. It cannot represent the European *P. violacea* because the mode of origin of its branches in relation to the trichoblasts is different from that distinctive of *P. violacea* as described by Falkenberg (1901, p. 116). It bears some superficial resemblance to *P. fibrillosa* Grev., but lacks the recurved branchlets. Furthermore, that species has

the branches arising in the axils of the trichoblasts, a character in common with European *P. violacea*, with which many Continental students have united it. Our plant has the branches replacing the trichoblasts, not axillary to them, and appears to be undescribed.

Polysiphonia Novae-Angliae, sp. nov. — *Planta marina et littoralis*, vinaceo-rubra ex disco basali oriens, penicillos plus minusve pyramidales 8–15 cm. altos erectos formans, textura subspongiosa, deorsum sparsim, sursum dense ramosis; ramis alternis primariis locos trichoblastorum tenentibus in segmentis ramiferis, lateralibus late patentibus, majoribus corticatis; cellulis pericentralibus 4; ramulis alternis vel irregularibus, plerumque subfasciculatis; tetrasporangiis in serie vel recta vel spirali longitudinaliter ordinatis, raro alternis, in ramis simpliciter vel 3–4-pliciter furcatis; antheridiis cylindricis acuminatis, formatis in apicibus ramulorum ex furcis infimis trichoblastorum; pericarpis ureolatis, sessilibus vel breviter stipitatis in ramis superioribus. Tab. XXVI–XXVII, Figg. 2–5 (Specimina typica).

Plant from a basal disk, forming more or less pyramidal tufts 8–15 cm. tall, moderately soft in texture but spongy rather than slippery; color light to dark purplish red; alternately branched and with few branchlets below, above densely and finely branched; main branching somewhat coarse, the principal axes erect, straight, the lateral branches wide-spreading; the segments 600–850 μ diam., 250–600 μ long, with four pericentral cells about the axis; corticated, the cortications continued to the lesser branches, but variable in amount in different forms; upper branching alternate to irregular, more dense, so that the branch tips may be somewhat fasciculate; branchlets 85–100 μ diam., segments 40–70 μ long, ecorticate; primary branches developing without reference to the evident trichoblasts, probably replacing them on the supporting segments; tetrasporangia 70–85 μ diam., oval or subspherical, in straight or somewhat twisted series, or sometimes alternate in the thicker branchlets, which in the fertile part may fork 1–4 times, and reach 120–170 μ diam., the segments up to 90 μ long; free tetraspores 40 μ diam.; antheridia cylindrical and pointed at the tip, to spindle-shaped, formed near the tips of the branchlets, each replacing one side of the lowest fork of a trichoblast, not terminating in hairs, but often with a distinct projecting sterile axile cell at the tip, diameter 40–50 μ , length 135–175 μ ; pericarps broadly urn-shaped, 320–400 μ diam., sessile or very short-stalked on the upper branches.

Type locality Black Rock, New Bedford Harbor, southern Massachusetts; growing in shallow water exposed to heavy wave action; collected by W. R. Taylor, July 25, 1935.

UNIVERSITY OF MICHIGAN

LITERATURE CITED

- COLLINS, F. S. 1900. Preliminary Lists of New England Plants, V. Marine Algae. *Rhodora*, 2: 41-52.
- 1909. The Green Algae of North America. *Tufts College Studies*, 2(3): 79-480.
- FALKENBERG, P. 1901. Die Rhodomclaccen des Golfes von Neapel und der angrenzenden Meeresabschnittes. *Fauna und Flora des Golfes von Neapel*, 26: 1-754.
- FARLOW, G. W. 1881. The Marine Algae of New England. *Rep. U. S. Comm. Fish and Fisheries for 1879, Appendix A-1 (1882)*: 1-210.
- HARVEY, W. H. 1846-51. *Phycologia Britannica*. London.
- 1849. *A Manual of the British Marine Algae*. London.
- 1853. *Nereis Boreali-Americana*. *Smithsonian Contributions to Knowledge*. Part 2. Washington.
- HOWE, M. A. 1914. The Marine Algae of Peru. *Mem. Torr. Bot. Club* 15: 1-185.
- KUNTZE, O. 1891-98. *Revisio Generum Plantarum . . .*, 3: 419.
- SETCHELL, W. A., AND GARDNER, N. L. 1920, 1925. The Marine Algae of the Pacific Coast of North America. *Univ. Calif. Publ. Bot.*, 8 (1920): 139-374; *ibid.*, 8 (1925): 383-898.

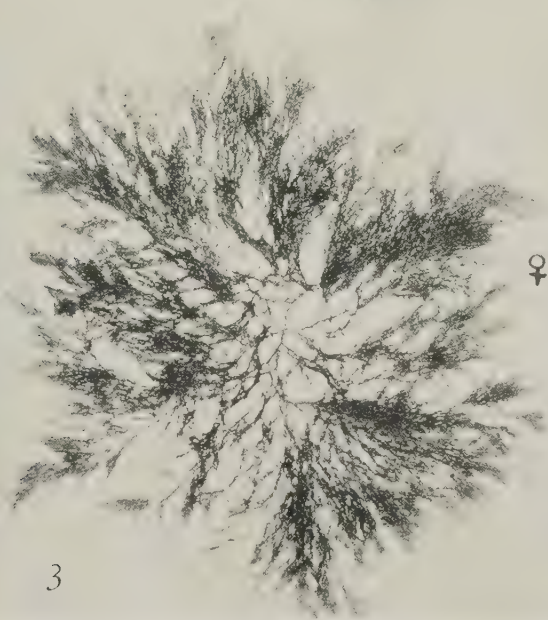
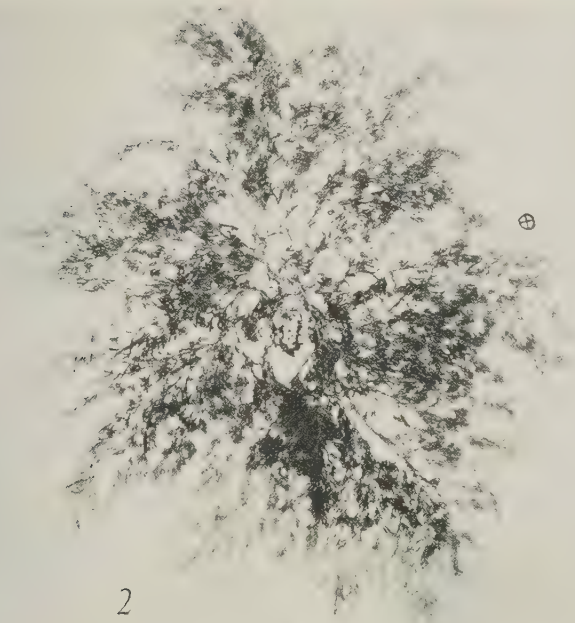
PLATES XXV-XXVII

PLATE XXV



FIG. 1. Habit of portion of *Desmarestia aculeata* var. *attenuata*, $\times 0.37$

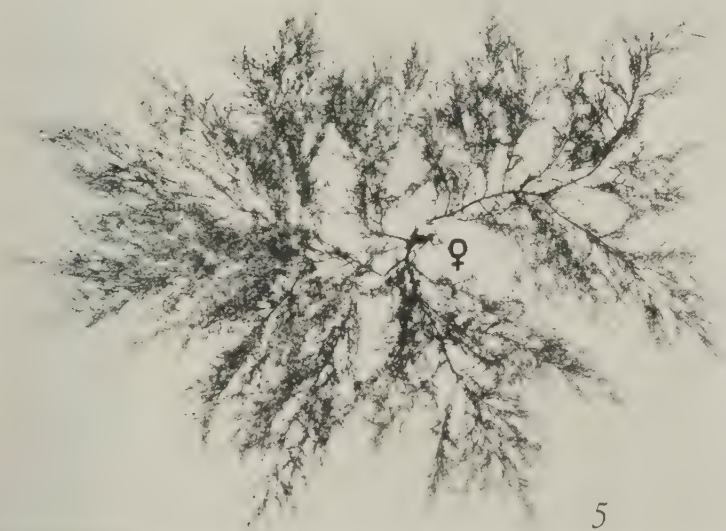
PLATE XXVI



Habits of *Polysiphonia Novae-Angliae*

FIG. 2. A tetrasporic plant, $\times 0.8$

FIG. 3. A cystocarpic plant, $\times 0.8$



Habits of *Polysiphonia Novae-Angliae*

FIG. 4. An antheridial plant, $\times 0.8$

FIG. 5. A cystocarpic plant (*Phyc. Bor.-Am.* 595a), $\times 0.8$

VEGETATIVE ANATOMY OF THE TOMATO (*LYCOPERSICUM ESCULENTUM* MILL.)

II. LEAF STRUCTURE

EDWARD F. WOODCOCK

INTRODUCTION

IN AN earlier paper the writer (5) presented the results of investigations on the stem anatomy of the tomato. The results here recorded concerning the leaf have been obtained by a further study of the vegetative anatomy.

The early investigators, Hanstein (3) and Peterson (4), in their studies of the Solanaceae, did not include a careful investigation of the anatomy of the tomato. The studies made by the writer (5) on the stem and the leaves of the tomato show that they are very similar in structure to those of the potato (*Solanum tuberosum*), investigated by Artschwager (1). Cooper (2), in his work on the anatomy and the development of the tomato flower, shows photographs in which leaves and epidermis hairs appear, but no statement is made concerning their structure.

MATERIAL AND METHODS

The leaves for study were obtained from material grown in the greenhouse. An interpretation of the course of the vascular bundles was obtained by an examination of complete cleared leaves and stained microtome sections. The stain used was methyl green and Bismarck brown.

GROSS MORPHOLOGY

The alternate leaves are spirally arranged on the stem and are slightly enlarged at the point of attachment to it. No stipules were observed on either young or old leaves. The first or primary leaves appearing above the two cotyledons are much simpler than the older leaves. This difference is well shown in text Figure 8. The leaves are pinnately compound, with small, nearly entire, short-stalked

leaflets interposed between the larger notched or lobed leaflets. The leaves, when young, are covered with closely placed hairs. As they mature the hairs become more separated, owing to the enlargement of the epidermal cells. Since, in the maturing of the leaf, there is



FIG. 8. *A*, primary leaf of a tomato plant; *B*, secondary leaf. $\times \frac{1}{2}$

The figures connected with the broken lines indicate the location of the cross sections shown in Plate XXVIII

much greater increase in area in the blade than in the petiole, the hairs on the blade are much farther apart and more abundant along the veins than elsewhere. The petiole, as it leaves the stem, is somewhat flattened along its ventral side. The rachis of the blade is divided into two furrows by a prominent ridge along its ventral side. The leaflets are pinnately veined and have a smooth margin.

ANATOMY

The hairs have a distinct variation in size and structure, as is shown in Plate XXVIII, Figure 6, and Plate XXIX, Figure 1. The two larger, several-celled pointed types (Pl. XXIX, Fig. 1, *A-B*) can be easily seen without the aid of the hand lens. The smaller of these two types arises as an outgrowth from a single epidermal cell, which is not raised above the level of the adjacent cells. The terminal cell has a rounded apex. The larger pointed hair, which is quite evident to the eye, is supported by a distinct enlargement on the surface of the leaf (Pl. XXVIII, Fig. 2). The terminal portion of the hair is very slender, and the end cell has a slightly enlarged portion at its apex. The two shorter, less easily seen hairs (Pl. XXIX, Fig. 1, *C-D*) present more variation than the two just described, and they arise as an outgrowth from an epidermal cell which is on the same level as the adjacent cells. One of these is made up of several somewhat cylindrical cells, the terminal cell having a pointed apex. The other short hair is a gland type. Its main axis consists of an elongated cylindrical cell, a short cylindrical cell, and a short taper-pointed cylindrical cell (Fig. 5). About the taper-pointed cell are radially placed four somewhat spherical cells (Fig. 4). Each of these cells is filled with rather dense cytoplasm, a nucleus, and several vacuoles containing a yellowish green oily substance. The contents of these gland cells, when allowed to escape upon rupture of the gland, give off the characteristic odor and the yellowish green stain evident when a person handles the plants.

As seen in cross section, the leaf traces or bundles near the base of the petiole form a crescent open toward the ventral side of the petiole (Pl. XXVIII, Fig. 1). The leaf-trace bundles are limited on the outside by the endodermis and the pericycle and on the inside by the pith. Each of the lateral bundles, which sometimes consist of two or three somewhat fused bundles, is larger than the dorsal bundle. The small ventral bundles arise as branches from the lateral bundles as they enter the base of the petiole.

The epidermis of the petiole is separated from the collenchyma of the cortex by a subepidermis consisting of a single layer of thin-walled, loosely arranged cells (Pl. XXIX, Fig. 2). The few stomata on the stem have kidney-shaped guard cells (Fig. 3) and typical

wall thickening (Fig. 2). Each stoma, with its guard cells, is at the top of a slightly elevated portion of the epidermis. Below each stoma is a substomatal air space. The outer periclinal walls of the epidermal cells are somewhat dome-shaped and have only a thin layer of cutin deposit. The anticlinal walls (Fig. 3) are quite straight in contrast to the wavy condition evident in the epidermis of the leaf blade. The long axis of the radially flattened epidermal cells is parallel with the long axis of the petiole.

The collenchyma region (Pl. XXVIII, Figs. 1-2; Pl. XXIX, Fig. 2) is several cells in thickness and forms a continuous layer around the petiole. The longitudinal wall thickening usually occurs at the corners of the cells. Occasionally the thickening extends across the tangential wall, thus giving the collenchyma region a stratified appearance. The collenchyma cells are usually separated by several parenchyma cells from the endodermis, which is made up of thin-walled cells with slightly developed casparian strips (Pl. XXX, Fig. 5). Intercellular spaces occur between the parenchyma cells.

Both the large and small bundles present the bicollateral arrangement of the vascular tissues. In cross section the tissues appear as shown in Plate XXVIII, Figure 3, and Plate XXX, Figure 5. Since there is no secondary thickening in the petiole all the tissues present are primary. The tracheary elements are thick-walled structures separated by xylem parenchyma cells and are of the ringed and spiral type. The phloem exists as small groups of thin-walled cells placed at an equal distance from the outside and the inside of the xylem. The outer phloem is separated from the xylem by a cambium zone made up of a few layers of irregular cells. Thin-walled irregular cells separate the inner phloem groups from one another and from the xylem. Parenchyma cells of irregular size separate the outer phloem groups from one another. The pericycle consists of a single layer of parenchyma cells separating the endodermis from the phloem and the parenchyma groups.

The phloem groups each consist of sieve tubes, companion cells, and conducting parenchyma. The location with respect to one another and to the xylem is quite uniform for both the outer and the inner phloem.

The large lateral bundles are connected with the dorsal bundle by a narrow zone which consists of the endodermis on the outside

and phloem groups scattered among small parenchyma cells on the inside (Pl. XXVIII, Fig. 1). In this intermediate region between the bundles there is no indication of cambium, xylem, or internal phloem. The two small ventral bundles are not connected with the large lateral bundles by such a distinct zone of cells.

The internal structure of the rachis (Fig. 4) varies somewhat from that of the petiole. The two small ventral bundles are still evident, but the two lateral bundles and the dorsal bundle have fused to form a single trough-shaped vascular bundle, the open side being toward the ventral side of the rachis. The xylem elements are arranged in rather distinct radial rows; the phloem groups are arranged as in the petiole. The collenchyma in the ventral region of the rachis is localized at the top of each of the three ridges and is not separated from the epidermis by a subepidermal layer, as is the epidermis in the other parts of the rachis.

The stalk of the leaflet at the base of the leaflet blade has the same general shape and structure (Fig. 5) as the rachis. In Figure 5 it is evident that one of the lateral ridges has been replaced by the lamina on one side of the leaflet and that the small ventral bundle on that side has passed into the lamina of the leaflet.

The internal structure of the leaflet lamina is shown in Plate XXX, Figure 3, and is quite similar to that of the potato (*Solanum tuberosum*) as described by Artschwager (1). The upper epidermis is only slightly thicker than the lower, and each consists of one layer of cells. Both epidermises have wavy anticlinal walls (Figs. 1-2). Stomata rarely occur in the upper epidermis, but are abundant and irregularly arranged in the lower epidermis. The guard cells which surround each stoma have typical wall thickening and are about half as thick as the adjacent epidermal cells. The elevated position of the guard cells evident in the petiole does not occur in the leaflet lamina. The mesophyll consists of a single layer of rather closely placed palisade cells and a spongy region of loosely arranged, somewhat rounded cells. Numerous small spherical chloroplasts occur in the mesophyll cells. The midrib and main lateral veins of the leaflet lamina have a trough-shaped vascular bundle, which gives off smaller branches from its ventral edges. The small veins are in contact with the palisade region and are bicollateral, with no indication of cambium present.

The course of the vascular tissue through the leaf and the

various fusions and divisions which occur are shown in the diagram (Pl. XXX, Fig. 4). As the vascular tissue supplying the leaf passes from the vascular cylinder of the stem it consists of a small median dorsal leaf trace and two larger lateral traces. In the basal region of the petiole there is cut off from each of the lateral traces a small trace toward the ventral side of the petiole. Each of the lateral traces consists of two or three somewhat fused bundles. The lateral traces and the dorsal trace fuse as they enter the rachis region of the leaf to form a trough-shaped vascular bundle, which continues the length of the rachis. Similarly shaped bundles arise from this bundle to serve as the main vascular supply for the leaflets. Each of the two small ventral traces of the petiole remains separate from the other vascular tissues as they enter the rachis and passes out into the leaflet to form one of the first lateral veins at the base of the leaflet. The opposite lateral vein arises as a branch from the edge of the trough-shaped vascular region just as it enters the base of the leaflet stalk. Soon after passing beyond the first leaflets the trough-shaped vascular bundle gives rise to a small bundle from each edge, so that the cross section of the rachis at this point presents the same appearance as below the first leaflets.

SUMMARY

The leaves of the tomato are pinnately compound and rather thickly covered in their young stage with four types of hairs. Three of these types are somewhat pointed, unbranched, and several-celled. The fourth type is gland-tipped. The epidermis is separated from the collenchyma of the cortex, in practically all parts of the petiole, rachis, and leaflet stalks, by a subepidermal layer. The vascular tissue is of the bicollateral type, and the leaf traces appear in the form of a crescent when seen in cross section. In the petiole the vascular tissue consists of one small dorsal trace, two large lateral traces, and two small ventral traces. In the base of the rachis the lateral traces and the dorsal trace fuse to form a trough-shaped vascular bundle which constitutes most of the vascular supply for the rachis and the leaflets. The first opposite lateral veins at the base of the first leaflets arise as a continuation of one of the small ventral traces and as a branch from one edge of the trough-shaped vascular bundle entering the leaflet stalk. Soon after passing beyond the point of origin of the leaflets the trough-shaped bundle of the rachis

gives rise to a small ventral trace from each ventral edge. Each of the two epidermises of the lamina has a single layer of cells of about the same thickness. The mesophyll consists of loosely arranged spongy tissue and a single layer of closely placed palisade cells.

MICHIGAN STATE COLLEGE
EAST LANSING, MICHIGAN

LITERATURE CITED

1. ARTSCHWAGER, E. F. 1918. Anatomy of the Potato Plant with Special Reference to the Ontogeny of the Vascular System. Journ. Agric. Res., 14: 221-252.
2. COOPER, D. C. 1927. Anatomy and Development of the Tomato Flower. Bot. Gaz., 83: 399-411.
3. HANSTEIN, J. L. E. R. VON. 1864. Die Milchsaftegefäss und die verwandten Organe der Rinde. 92 pages, 10 pls. Berlin.
4. PETERSON, O. G. 1882. Über das Auftreten bicollateraler Gefässbündel in verschiedenen Pflanzenfamilien und über den Werth derselben für die Systematik. Bot. Jahrb. (Engler), 3 (4): 359-402, pls. 4-8.
5. WOODCOCK, EDWARD F. 1936. Vegetative Anatomy of the Tomato (*Lycopersicum esculentum* Mill.) I. Stem structure. Pap. Mich. Acad. Sci., Arts and Letters, 21 (1935): 215-222.

EXPLANATION OF PLATES XXVIII-XXX

Leaf of *Lycopersicum esculentum* Mill.

Abbreviations: CA, cambium; CH, chloroplast; CO, collenchyma; CS, caspian strip; EN, endodermis; EP, epidermis; GC, guard cell; GL, gland; HA, hair; IP, inner phloem; IS, intercellular space; LE, lower epidermis; OP, outer phloem; P, phloem; PA, palisade; PE, pericycle; SC, substomatal chamber; SE, subepidermis; SP, spongy tissue; SPT, spiral tracheid; ST, stoma; UE, upper epidermis; X, xylem; XP, xylem parenchyma.

PLATE XXVIII
(Photomicrographs)

- FIG. 1. Cross section of petiole at region indicated by broken line (1) in text Figure 8, showing the five leaf traces arranged in the form of a crescent. Each of the large lateral bundles is somewhat divided. The outer phloem groups are continuous, while the internal groups occur only opposite the xylem. $\times 15$
- FIG. 2. A portion of petiole cross section showing base of long hair, epidermis, subepidermis, collenchyma, parenchyma of cortex, endodermis, pericycle, and outer phloem groups scattered among small parenchyma cells. $\times 45$
- FIG. 3. Cross section of vascular bundle and adjacent region showing parenchyma of cortex with intercellular spaces, endodermis with slightly developed casparian strips, pericycle of one layer of cells, outer phloem groups scattered among parenchyma cells, weakly developed cambium, spiral and annular tracheids scattered among xylem parenchyma cells, and parenchyma of pith with intercellular spaces. $\times 50$
- FIG. 4. Cross section of rachis at region indicated by broken line (2) in text Figure 8, showing the three prominent ridges on the ventral side. Beneath the epidermis of each ridge is a group of collenchyma cells, and in all other regions a subepidermal layer. The remaining tissues are as in the petiole. The two lateral vascular bundles and the dorsal bundle have fused to form a single crescent-shaped bundle with somewhat radially arranged xylem cells. $\times 24$
- FIG. 5. Cross section of stalk of leaflet and lamina at region indicated by broken line (4) in text Figure 8, showing the same condition as in the rachis, Figure 4, except that one of the lateral ventral ridges has been replaced by the lamina of the leaflet. A cross section of the leaflet stalk through the region indicated by the broken line (3) in text Figure 8 appears much the same as the section through (4). $\times 20$
- FIG. 6. A portion of the petiole, showing the relative length of the straight, somewhat pointed hairs and the gland-tipped hairs. $\times 3$

PLATE XXVIII

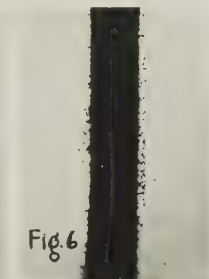
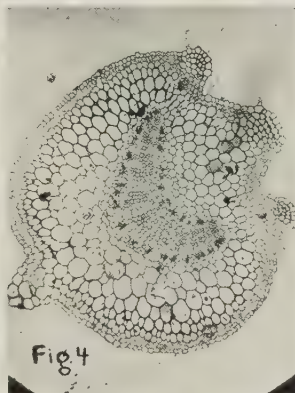
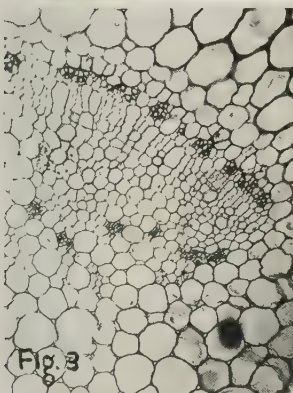
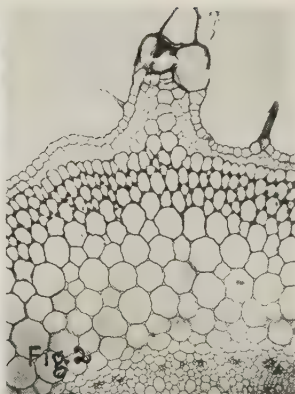
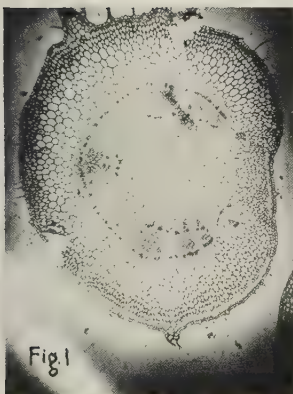


PLATE XXIX

(Camera lucida drawings)

- FIG. 1 (*A, B, C, D*). The four types of hairs in side view drawn to the same scale to show relative length and structure. $\times 16$
- FIG. 2. Cross section through epidermis, stoma, loosely arranged subepidermis, and collenchyma of petiole. $\times 207$
- FIG. 3. Surface view of epidermis of petiole, showing the nearly straight anticlinal walls, stoma, and hair. $\times 207$
- FIG. 4. Top view of gland-tipped hair, showing the four somewhat rounded gland cells. $\times 207$
- FIG. 5. Longitudinal section of gland-tipped hair, showing the main axis terminated by a slender cell about which are arranged the gland cells. $\times 207$

PLATE XXIX

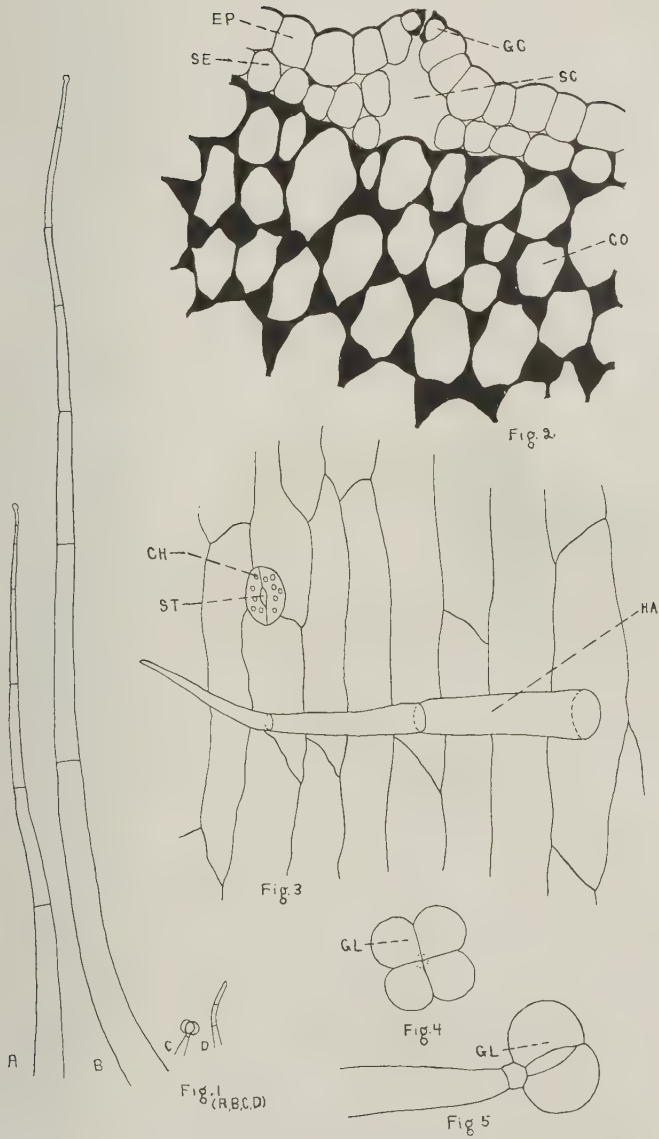


PLATE XXX

(Camera lucida drawings, except Figure 4, which is a diagram)

- FIG. 1. Surface view of lower epidermis of lamina, showing wavy anticlinal walls and irregularly arranged stomata. $\times 207$
- FIG. 2. Surface view of upper epidermis of lamina, showing wavy anticlinal walls (solid lines) and end view of palisade cells (broken lines). $\times 207$
- FIG. 3. Cross section of lamina, showing upper and lower epidermis stoma, palisade tissue, spongy tissue, intercellular spaces, chloroplasts, phloems, and xylem. $\times 207$
- FIG. 4 (*A, B, C, D*). Diagram of petiole, rachis, stalk of leaflet, and base of a leaflet lamina, showing the changes which occur in the extent, shape, and course of the vascular tissue
- FIG. 5. Cross section of endodermis, pericycle, and vascular region of petiole. Casparian strips appear on the radial walls of the endodermis. The outer phloem groups are separated from one another by parenchyma cells and from the endodermis by a pericycle consisting of one layer of thin-walled cells. The cambium is weakly developed and the xylem, which is primary, is made up of ringed and spiral tracheids separated from one another by xylem parenchyma. The inner phloem groups are separated from one another and from the xylem by parenchyma cells. $\times 207$

PLATE XXX

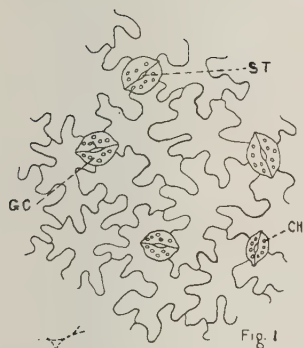


Fig. 1

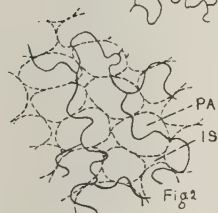


Fig. 2

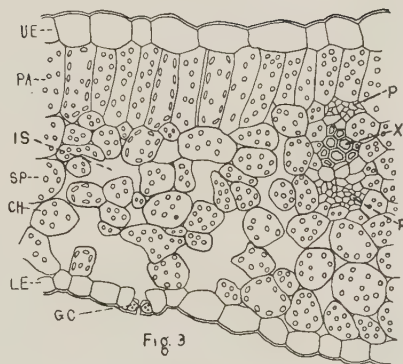


Fig. 3

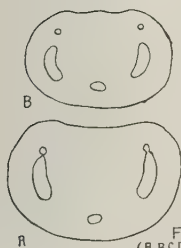
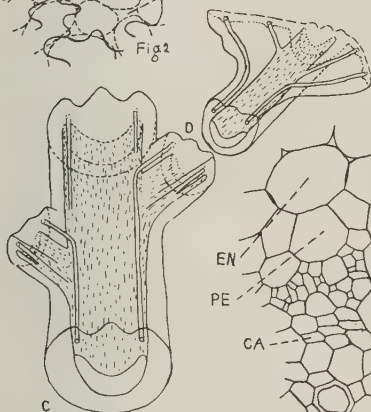


Fig. 4
(A, B, C, D)

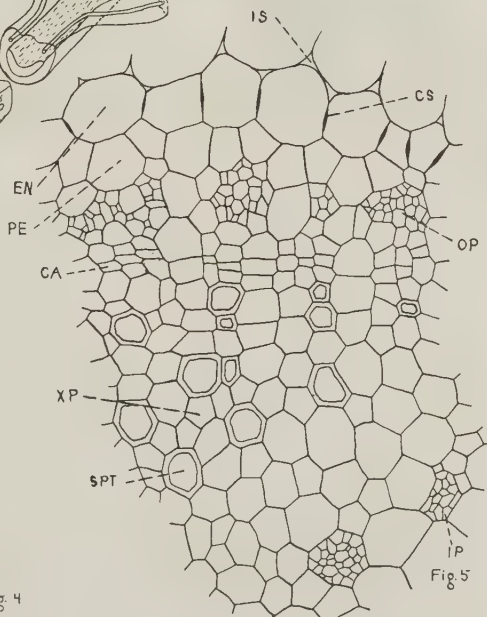


Fig. 5

MARX VS. MALTHUS

SAMUEL M. LEVIN

FOR more than a century and a quarter the world has been interested in the Malthusian population theory; for more than three quarters of a century it has had to reckon with the economic conceptions of Karl Marx. Though Marx roamed over a wide-flung economic domain, it is not generally recognized that he had significant contributions to offer on the subject of population. This may be due to the fact that his ideas in this sphere were in the main incidental to his consideration of the mechanism of capitalistic production, with its investiture of surplus value and the adjunct factors of accumulation, concentration, and centralization. This approach led to a consideration of the effect of the increase of constant capital (means of production) on wages and employment; of absolute and relative redundancy of numbers, of the relationship between the course of the industrial cycle and the labor reserve, and a miscellany of kindred subjects.

The contrast between the views of Marx and Malthus is of no slight importance at the present time. Malthus used his theory of natural increase and checks as a practical yardstick or frame of reference. The principle of population, with its stern insistence on natural law and individual responsibility, was resorted to as a useful test of the validity of received opinion on the improvement of society, the function of institutions, the practicability of the poor laws, war, crime, education, the socialization of property ownership and income, and sundry other items of importance to society. With Malthusianism on one side and the Marxian emphasis on the socializing and evolutionary processes of production on the other we have, represented before us, two contravening interpretations of economic development, two idea systems immanent in the conflicts and confusions of contemporary society. Since about half a century elapsed after the appearance of Malthus' first edition of the *Essay on Population* before Marx began his serious work, a deeper insight

on his part into the nature of modern capitalistic economy was, of course, to be expected. It would not be surprising, therefore, to find him adopting a critical attitude toward Malthus, say, in the manner of Senior or Bagehot. But in addition to being a critic, Marx was the creator of a radically new outlook, a new fabric of thought with its fantastic and disquieting patterns, strangely different from what the protagonists of individualism had been accustomed to.

That Marx's views on population are an amazing contrast to those of Malthus is clearly evidenced by a comparison of their respective thoughts on the crucial problems in this field.¹ Marx evinces no disposition to concern himself with the proposition that plays a principal rôle in the Malthusian system: the constant tendency of population to increase beyond the means of subsistence. This does not mean that he is oblivious to the phenomenon of natural increase, or, to use his own terms, "the actual increase" or "the absolute growth of the population."² But such absolute growth is not construed as the vital element in the situation. The real problem of population under capitalism, according to Marx, is the creation of the "disposable industrial reserve army" necessary for the expansion of the scale of production, independently of the limits of the actual increase of population. Whereas Malthus uses the term "principle of population" in the sense of a law, identifying it with "the laws of Nature which are the laws of God," Marx objects to the notion of a general, all-embracing law. He offers instead "a law of population peculiar to the capitalistic mode of production" on the ground that

¹ Marx's comment on Malthus evinces an attitude of scornful depreciation. The first edition of Malthus' *Essay on Population*, he says, "does not contain a single sentence thought out by himself." He proceeds: "... the great sensation this pamphlet caused was due solely to party interests. The French Revolution had found passionate defenders in the United Kingdom; the 'principle of population' slowly worked out in the 18th century, and then, in the midst of a great social crisis, proclaimed with drums and trumpets as the infallible antidote to the teachings of Condorcet &c. was greeted with jubilation by the English oligarchy as the great destroyer of all hankering after human development. Malthus, hugely astonished at his success, gave himself to stuffing into his book materials superficially compiled and adding to it new matter, not discovered but annexed by him." Karl Marx, *Capital, A Critique of Political Economy*, edited by Frederick Engels (Charles H. Kerr & Co., Chicago, 1921), I: 675-676. See also Marx's letter to Schweitzer, dated January 24, 1865. In this letter he stigmatizes "Malthus' book On Population" as a libel on the human race. Karl Marx and Friedrich Engels, *Correspondence, 1846-1895* (International Publishers), p. 170.

² *Capital*, I: 693-695.

"every special historic mode of production has its own special laws of population, historically valid within its limits alone."³

It is this relative surplus, this plethora of the labor reserve, induced by modern industrialism, that Marx puts in the center point of attention. This to him is the challenging aspect of overpopulation in modern industrial society. "It is capitalistic accumulation itself," he tells us, "that constantly produces and produces in the direct ratio of its own energy and extent, a relatively redundant population of laborers, i.e., a population of greater extent than suffices for the average needs of the self-expansion of capital, and therefore a surplus population."⁴

The greater part even of Malthus' disquisition on population concerns itself with the problem of the increase of the *lower classes*. To Marx, however, such augmentation of numbers is no evidence of a "constant tendency." The pressure is not that of population on subsistence, but of the dominating groups in the capitalistic system

³ *Ibid.*, p. 693. On this point see Engels' letter to F. A. Lange, dated March 29, 1865. Marx and Engels, *op. cit.*, p. 198. Some years before Marx's *Capital* appeared Archibald Alison had already propounded the idea "that the welfare of mankind requires that different laws should regulate the progress of population at different periods of its progress." *The Principles of Population* (London, 1840), I: 9. Malthus disdained this sort of pluralism. Even in the first edition of the *Essay* he wrote, pp. 365-366: "Unless the principle of population were to be altered according to the circumstances of each separate country (which would not only be contrary to our universal experience, with regard to the laws of nature, but would contradict even our own reason . . .) it is evident that the same principle, which seconded by industry will people a fertile region in a few years, must produce distress in countries that have been long inhabited." See also reprint of Seventh Edition of *Essay on Population* (Everyman's Library), II: 158.

⁴ Marx, *op. cit.*, I: 691. Marx points out that even Malthus recognized "overpopulation as a necessity of modern industry," citing in corroboration some lines from the latter's *Principles of Political Economy*. He states (*ibid.*, pp. 695-696), however, that Malthus explained this overpopulation by "the absolute growth of the laboring population, not by their becoming relatively super-numerary." It is to be noted that Malthus, too, distinguished between relative and absolute. ". . . everything depends," he wrote (Everyman's Library, II: 261), "upon the relative proportion between population and food, and not on the absolute number of people." Once the proper proportioning between population and food was accomplished, "population might continue to increase for ages." But the Malthusian conception of a relative proportion was something altogether different from that of a relative surplus produced by capitalistic accumulation. It implied an adjustment between numbers and food in terms of prudential or moral restraint, with a resulting absolute increase if warranted by the supply of food. The effort of population to increase beyond subsistence thus placed the problem of absolute increase in the foreground.

on labor. The natural increase of the proletariat, instead of illustrating the effort of population to reach the limit of subsistence, is merely a normal reaction to their exceptionally high death rates and a response to the demand for an abundant crop of youthful laborers. There is, in fact, an undersupply of young workers at the very time when the adult quota is overfull.⁵

There is the further point, adverted to by Marx, that "the number of births and deaths" and "the absolute size of the families" stand in inverse proportion to the height of wages and the accompanying means of subsistence. Hence the actual relation between population and subsistence is the opposite of what Malthus imagined, and the high birth rates (i.e. the rapid renewal of the generations of laborers) are not an indication of a necessary tendency, a constant pressure on subsistence, or improvidence on the part of men and women in the lower ranks of society. Their early marriage, merely an adjustment to a social need, is "a necessary consequence of the conditions in which the laborers of modern industry live," and of "the premium that the exploitation of children sets on their production."⁶

But what of the checks which Malthus made so much of, regarding, as he did, the study of the operation of the checks in human society, in the past and the present, as his principal contribution? There is nothing in Marx to indicate that he deemed them a matter of weight in the discussion of the population problem. Since the checks of vice, misery, and moral restraint are in the Malthusian sense the outcome of the pressure of population on subsistence, a point of view so obviously in disaccord with such pressure as the Marxian was tantamount to their disestablishment. Marx recognizes an adjustment, to be sure, but it is an adjustment of population to the requirements of capital, instead of to the means of subsistence. It is not based on the geometric and arithmetic ratios. It is effected, not by food, but by "the mechanism of capitalist production and accumulation."⁷ Vice, misery, and moral restraint are not germane to this aspect of the problem, and far from holding the vantage

⁵ Marx, *op. cit.*, I: 704.

⁶ *Ibid.*, pp. 704-706. "This incessant reproduction, this perpetuation of the laborer is a sine qua non of capitalistic production" (p. 625), also, "the maintenance and reproduction of the working class is and must ever be, a necessary condition to the reproduction of capital" (p. 627).

⁷ *Ibid.*, p. 707.

ground in the discussion of population that Malthus accords them, their function as checks is to all intents and purposes buried in oblivion.

In the light of this conception of the motives for the reproduction of laborers how does Marx deal with "means of subsistence"? The familiar Malthusian propositions are that population is limited by the means of subsistence and that it invariably increases where the means of subsistence increase, unless prevented by the checks of vice, misery, and moral restraint. Marx uses the term "means of subsistence" to describe the laborer's consumption. "The laborer," he says, "turns the money paid to him for his labor power into means of subsistence; this is his individual consumption," necessary for his living. But it is also through this consumption that "the muscles, nerves, bones, and brains of existing laborers are reproduced and new laborers are begotten."⁸ He proceeds: "Within the limits of what is strictly necessary, the individual consumption of the working class is, therefore, the reconversion of the means of subsistence given by capital in exchange for labor power, into fresh labor power at the disposal of capital for exploitation."

Thus even the individual consumption of the laborer is a part of the process of capitalistic production. Though the maintenance and reproduction of the working class is a condition of the reproduction of capital, the "capitalist," says Marx, "may leave its fulfilment to the laborer's instincts of self-preservation and propagation." But the needs of capital are in the ascendant. It is these needs that determine the laborer's response. There is no place for self-determination. The working class is merely an appendage.

The Marxian thesis leads to the conclusion that neither prior existence of food nor the increase of such food accounts for the growth of population, for the means of subsistence flow from the capitalistic process, and this process has no definable limits. If the laborer's consumption is reduced to the bare requirements of maintaining and reproducing his class, the situation is not due to the fact that the power of food to increase is less than that of population, but to the disparity between what capital awards to labor and what it reserves to itself. The very necessities with which laborers are sustained are parts of the capitalistic product. Finally, under the influence of "the law of capitalistic society," that the number of births and

⁸ *Ibid.*, p. 626.

deaths and the absolute size of the families "stand in inverse proportion to the height of wages," procreation is actually checked with an increase of means of subsistence and vice versa.

Marx's interpretation has some kinship to the Ricardian point of view in recognizing the salient importance of capital as the direct factor bearing on the employment of labor.⁹ Since there is the instinct for propagation, and since wages suffice not only for maintenance but for growth, the natural increase is a response to the growing demand on capital's part for new labor power. Indeed, he acknowledges that the requirements of accumulation of capital may exceed the increase of labor power or the number of laborers. The demand for laborers may exceed the supply and therefore wages may rise, but the background of this increase is capitalistic. "Accumulation of capital," he says, "is . . . increase of the proletariat."

Marx evidently sees no need for moral restraint (Malthus' principal remedy for the evils of overpopulation) and does not mention it, save as a gibe against the parsons. Men and women are not admonished to resort to moral restraint or any other method of birth control. The mention of the inverse proportion between the absolute size of families and the height of wages indicates that he knew of the existence of measures of birth restriction, but he regards this situation as a law of capitalistic society. His personal repugnance to such a state of affairs is seen in his designating it as something which "would sound absurd to savages or even civilized colonists." "The folly," Marx writes, "is now patent of the economic wisdom that preaches to the laborers the accommodation of

⁹ "Population regulates itself by the funds which are to employ it, and therefore always increases or diminishes with the increase or diminution of capital," D. Ricardo, *The Principles of Political Economy and Taxation* (Everyman's Library, 1912), p. 41. In the chapter entitled "Malthus on Rent" Ricardo writes (p. 277): ". . . the general progress of population is affected by the increase of capital, the consequent demand for labour, and the rise of wages; and . . . the production of food is but the effect of that demand." Marx, however, parted company with Ricardo and the economists in insisting that the importance of accumulation is not in its direct effect on numbers, but in producing a relative surplus. In the event of greater accumulation "it is not the diminished rate either of the absolute, or of the proportional increase of labor power or laboring population which causes capital to be in excess, but conversely, the excess of capital that makes exploitable labor power insufficient. In the second case [slackening of the rate of accumulation] . . . it is . . . the relative diminution of capital that causes the exploitable labor power, or rather its price to be in excess." Marx, *op. cit.*, I: 679. See also pp. 699-700.

their number to the requirements of capital," since the mechanism of production and accumulation takes care of it. And the answer to Malthus' earnest plea for postponement of marriage is the already mentioned fact that the early marriage of the laborer is a response to the social need of a continuously replenished labor supply.

In this respect the Marxian treatment of population differs from those of other writers, such as William Thompson, preceding him, and August Bebel and Bernard Shaw, following him. He was interested in analyzing the nature of the capitalistic process and the modes of economic change and their effects on society. The problem of numbers was intertwined with a score of others. It was not singled out for special consideration, as with the foregoing writers, or prompted by the desire to vindicate socialist expectations on this score against unfriendly critics.

As to the positive check of misery, it is to be noted that Marx did not envisage it (in the Malthusian style) as a penalty for the worker's lack of foresight, prudence, and restraint, for overpopulation with its blight of misery was needed for the expansion of capital. That labor was wraped in misery he did not deny. Indeed, he insisted that the lot of the laborer was always growing worse, as shown in the differential death rates of the laboring class, in the exploitation of mothers and children, in accidents, industrial disease, and the spread of pauperism. But these are stigmata of the system, for which such things as surplus value, the changing technical composition of capital, and capitalistic accumulation are to be blamed and not the laborer's instinct. They are not "terrible correctives to the redundancy of mankind," occasioned by the too rapid increase of population. The high death rates are not indications that we have offended against some of the laws of nature. Nor would Marx regard the disease and death flowing from dirt, squalid poverty, and indolence as a "benevolent dispensation."¹⁰ He would undoubtedly say that, far from being necessary, they are the results of forms of exploitation in the present historic stage of capitalistic production.

More important to Marx than means of subsistence are means of production. The term is used repeatedly. Accumulation increases the concentration of means of production in the hands of individual capitalists. It is the growing extent of the means of production

¹⁰ Malthus, *op. cit.*, II: 152-153.

as compared with labor power (i.e. the progressive increase of constant capital in proportion to variable capital or labor power, necessary for its employment)¹¹ that is at the bottom of the labor reserve.

The accumulation of capital proceeds by capitalistic reproduction. Indeed, it is a reproduction on a progressive scale, effected by the reproduction of labor power incorporating itself with capital. Accumulation, moreover, is conditioned by methods of raising the productive power of labor leading to an acceleration of this process.¹² In the end, under the "specifically capitalist mode of production" it manifests itself as "a constant increase of its constant at the expense of the variable constituent." This, then, is the Marxian constant tendency as against the tendency of population to increase at a more rapid pace than subsistence.

The law of population peculiar to the capitalist mode of production is stated in these words: "The laboring population . . . produces along with the accumulation of capital produced by it, the means by which itself is made relatively superfluous . . . and it does this to an increasing extent."¹³ This kind of relative superfluity occasions an overpopulation, but by a method different from the theory of natural increase propounded by Malthus. That method is the capitalistic process of accumulation effected by the appropriation of labor's surplus product, accelerated by the use of credit, and enhanced by the concomitant processes of concentration and centralization. The consummation of the movement manifests itself in a piling up of machinery, in larger and more powerful aggregates of capital, and in new and more efficient techniques of production.

¹¹ Here, too, the Marxian thought bears some kinship to the Ricardian, though Marx follows a tack of his own. Ricardo wrote (*op. cit.*, p. 264): "I am convinced that the substitution of machinery for human labor is often very injurious to the industry of the class of laborers . . . it follows if I am right, that the same cause which may increase the net revenue of the country may at the same time render the population redundant, and deteriorate the condition of the laborer."

¹² Marx suggests the interesting idea that in the childhood of capitalistic production the advance of accumulation found a check in the natural limits of the laboring population, i.e. population functioned as a check to capital. This is akin to a view expressed by Michael T. Sadler a generation earlier with regard to means of subsistence (*The Law of Population* [London, 1830], I: 109): "We assert directly the contrary, namely, that the means of subsistence are produced and limited by population."

¹³ Marx, *op. cit.*, I: 692.

An inseparable feature is a relative surplus, a supernumerary force needed for the free play and expansion of modern industry.

It is obvious from what has been said that Marx has impressed on the contemporary raw material of overpopulation the configuration of the modern problem of unemployment and underemployment. Specifically, he has constructed a theory of technological unemployment. His discussion of this subject leaves the impression of uncanny up-to-dateness. He cites the decline of employment in the various industries of England and Wales in 1861 as compared with 1851, e.g. in worsted manufacture, silk weaving, and hat making.¹⁴ In the cotton industry between 1861 and 1868, 338 cotton factories disappeared, the number of operatives decreased by 50,505, but the product increased. He shows how, as a result of maximizing the rapidity and intensity of labor, workmen earned (after the Ford fashion) in eleven hours as much wages as they had done before in twelve, or produced in eleven hours more than previously in twelve. He touches on the "automatic factory" which transforms the worker into a sort of "detail machine," at the same time lessening the expense of his reproduction; on the repulsion of laborers by old capital, and on the more difficult absorption of the superabundant numbers. He points to the relatively short working life of the modern industrial employee, the progressive replacement of skilled workers by less skilled, male by female, and adults by young persons or children.

While stressing these effects of machinery on labor, Marx nevertheless was obliged to admit that circumstances may occasion an absolute increase in the working population, e.g. under "special stimulus to enrichment" and the opening of new markets, or where the process of accumulation has given rise to an excess of capital. His pivotal point is that, with the growth of the total capital, the labor incorporated in it also increases, but in a constantly diminishing proportion.¹⁵

¹⁴ *Ibid.*

¹⁵ *Ibid.*, p. 690. Marx calls attention to a number of other important facts relevant to this problem, viz., that labor thrown out of work in any branch of industry may be benefited by new and added capital seeking investment. An immediate effect may be an increase of employment in other industries, though the capacity for increased employment would depend "on the extent to which machinery has already seized on or is then seizing on those trades." Another case favorable to employment is where the half-finished or intermediate product is still supplied by handicraft. He admits the possibility of augmented

There is no doubt that, from the Marxian standpoint, the phenomenon of the relative surplus is the crux of the problem of population. Therein is found the challenge of redundancy, rather than in the inevitable overgrowth of numbers, in the absence of the checks. It is the forms and the functions of this surplus that are all-important. "The intensity of competition among laborers," he tells us, depends wholly on its pressure. Even the general movement of wages is determined, not "by the variations of the absolute number of the working population," but by the expansion and contraction of the industrial reserve, a mass of human material always ready when needed.¹⁶ It is necessary for the expansion of the scale of production, independent of any other increase of population. It offers the possibility of throwing large masses of men on the decisive points of industry without diminishing the scale of production in other places. Thus it is inseparably linked with the industrial cycle, for the periods

employment in industries that produce luxuries, in the carrying trades, in the making of canals, docks, bridges, etc., and in the unproductive channel of domestic service. Marx concludes that with the extension of business and increase of capital or the introduction of more machinery in an industry, employment increases. Only in proportion to the total capital advanced do the numbers diminish. He puts it succinctly in these words: "Hence a relative decrease in the number of hands is consonant with an actual increase." *Ibid.*, p. 491

The microscopic inspection of the intricacies of capitalistic employment of machinery brings to light what Marx, himself, designates as a contradiction, namely, that the diminution of the number of workers is an obstacle to the increase in the rate of surplus value or profit, inasmuch as surplus value is derived from variable capital. It is this which at the outset prompts to an excessive lengthening of the working day (in order to squeeze more surplus value out of each worker), and with the advent of legislation for the shorter day, to further improvement of machinery and increased tension of labor power. The Marxian attempt (brought out posthumously) to resolve this contradiction by the possibility of a uniform rate of profit if "all employers are to be regarded as one group in which the surplus value gained by all is distributed among all," was met with a volume of adverse criticism. Alexander Gray, *The Development of Economic Doctrine* (London, 1931), p. 321.

¹⁶ "Every laborer," writes Marx (*op. cit.*, I: 703), "belongs to it during the time when he is only partially employed or wholly unemployed." The bearing of the Marxian analysis on the "iron law of wages" is adverted to in a letter that Engels wrote to Bebel in March, 1875. Engels' comment was as follows (Marx and Engels, *op. cit.*, p. 335): "Now Marx has proved in detail in *Capital* that the laws regulating wages are very complicated, that sometimes one predominates and sometimes another, according to circumstances, that therefore they are in no sense iron but on the contrary very elastic. . . . The Malthusian basis for the law which Lasalle copied from Malthus and Ricardo . . . has been refuted in detail by Marx in the section on the Process of Capital Accumulation."

of changing activity depend "on the constant formation, the greater or less absorption, and the reformation of the industrial reserve army of surplus population."¹⁷ The cycle in turn recruits the surplus and helps to reproduce it. The redundant mass is a force which in depression serves to weigh down the active labor army and, in periods of marked improvement, to impede labor's advances.

There are other elements in the Marxian treatment that offer a vivid contrast to the Malthusian. As against Malthus' simple terminology touching on the reproduction of the human species, we have an involved nomenclature dealing with the reproduction of labor power incorporated into capital, the reproduction of capital, the reproduction of the capital relation (i.e. the relation between capitalists and wage workers), and the reproduction of surplus. As against the workman burdened with "the principal blame" for his poverty, because of imprudent marriage or his endeavor to raise too many children, Marx places the responsibility on the productive process; as against Malthus' "narrow principle of self-interest which prompts each individual to exert himself in bettering his condition,"¹⁸ Marx puts his emphasis on social labor, social capital, social means of production, the social productive power of labor, and the synchronizing of the productive conditions of any given period with its technical advance. And as against "the retrograde and progressive movements of labor" that Malthus speaks of, we have the Marxian conception of an industrial cycle inseparably yoked to the labor reserve.

Malthus drew a picture of disastrous consequences that would inevitably ensue if a "system of equality" were to replace private property. The darkness of misery would then settle on the whole of society instead of enshrouding merely the lower classes. He envisioned a resulting scene of strife, desolation, and confusion. But to Marx ultimate dissolution was immanent in the existing order of inequality bound up with the order of capitalist domination. In

¹⁷ Marx, *op. cit.*, I: 694. A view akin to the Marxian, that capital requires an industrial reserve army "for its free play," is suggested in Sir William Beveridge's reference (*Unemployment* [1930], p. 13) to "the requirements in each trade of reserves of labor to meet the fluctuations of work incidental even to years of prosperity."

¹⁸ Malthus, *op. cit.*, II: 261. A factor offsetting this individual responsibility is deception by the higher classes of society as well as "encouragement to marriage from positive institutions and prevailing opinions." *Ibid.*, pp. 170, 185.

contrast to the Malthusian opinion that "the structure of society, in its great features, will probably always remain unchanged," and that "we have every reason to believe that it will always consist of a class of proprietors and a class of laborers," Marx endeavored to show that the present order of property ownership, individual enterprise, and profit is merely a stage in the industrial evolutionary process.

Both Malthus and Marx couple misery with population redundancy. The Malthusian misery is inclusive of vice, for the very reason an action is termed vicious is that its general consequence is misery. Though poverty was needed as a spur to industry, Malthus recognized that "the indigence which is hopeless destroys all vigorous exertion and confines the efforts to what is necessary for bare existence."¹⁹ The misery of the workers is a positive check to population, and moral restraint the remedy to prevent it. But this cannot be effected without incidental evils. Malthus even argued that "moral evil was absolutely necessary to the production of moral excellence."²⁰ He insists, however, that we are not patiently to submit to it, but to endeavor to avoid it. He stresses the belief that the tendency of population to increase faster than food is really necessary to overcome indolence, to improve human faculties, and to replenish the earth, but he does not tell us how society can steer safely between the individual's desire to escape poverty and these basic needs of man. His appeal to the individual may perhaps be logically sustained in the light of his insistence that moral restraint is possible at a cost of only temporary unhappiness. But the question remains of drawing the line between good and evil in a manner not to weaken the process of fostering exertion, replenishing the earth, and "forming mind out of matter."²¹

For Marx, misery is like a deepening gloom that finally enwraps the laboring class in the blackness of an impenetrable night. "In

¹⁹ Malthus, *op. cit.*, Second Edition, p. 475

²⁰ Malthus, *op. cit.*, First Edition, pp. 375, 395. See also Second Edition, p. 484.

²¹ In the first edition Malthus argues (p. 395) that "The continual variations in the weight [of evil] and in the distribution of this pressure, keep alive a constant expectancy of throwing it off." He also points out (*Everyman's Library*, II: 158) that with a balance between population and food, it is hard to see what motive "would be sufficiently strong to overcome the acknowledged indolence of man." "If the question be merely a question of degree," he avers, "... we may fairly distrust our competence to judge of the precise quantity necessary to answer the object with the smallest sum of incidental evil."

proportion as capital accumulates," he says, "the lot of the laborer . . . must grow worse."²²

Whereas Malthus recognizes a number of offsetting features, such as the oscillation from misery to plenty and the operation of certain "interrupting causes," rendering the condition of the laborer, for irregular periods, "tolerably comfortable," the Marxian interpretation of this problem is weirdly pessimistic. It foredooms the modern laborer to pauperism, a condition which "develops more rapidly than population and wealth." Pauperism, in turn, is a dead weight resting on the shoulders of the industrial reserve.

But there is another difference. To Malthus the misery of the lower classes, together with the habit of attributing this distress to the rulers, is "the rock of defense, the castle, the guardian spirit of despotism." In view of what has been done to human liberty in European countries in recent years these words of Malthus on the dangerous reactionary tendencies of a poverty-stricken rabble (save perhaps for regarding a natural pressure of population as the chief cause) acquire a special significance. "A mob which is generally the growth of a redundant population goaded by resentment for real sufferings but totally ignorant of the quarter from which they originate is of all monsters the most fatal to freedom."²³ But Marx, somewhat in the same vein, raised his voice in warning, not against the undifferentiated mass of redundant population, but against "the social scum," the "passively rotting mass thrown off by the lowest layers of old society." The increase in the number of the proletariat, on the other side, leads to growing strength, revolt, and a new economic and social order, one in which the full and free development of every individual forms the ruling principle.

Both Malthus and Marx predicate struggle. It was Malthus who first used the term "struggle for existence" in describing the contest which ensues when the overpopulation of a pastoral tribe forces out "young scions from the parent stock . . . to explore fresh regions and to gain happier seats for themselves by their swords."²⁴ Struggle was indeed immanent in the Malthusian system, a fact that explains the rôle that it played in the formulation of the theory of natural selection. Darwin himself wrote: "As more individuals are produced than can possibly survive, there must in every case be a struggle for

²² Marx, *op. cit.*, I: 708-709.

²³ Malthus, *op. cit.*, II: 187.

²⁴ *Ibid.*, First Edition, pp. 47-48.

existence, either one individual with another of the same species, or with the individuals of distinct species, or with the physical conditions of life. It is the doctrine of Malthus applied with manifold force to the whole animal and vegetable kingdoms, for in this case there can be no artificial increase of food and no prudential restraint from marriage."²⁵

Marx, on his part, propounds the theory of class struggle, which is something different from the Malthusian struggle for existence. Indeed, he criticizes the "struggle for life" derived from the Malthusian law of population or overpopulation, on the ground that it fails to analyze the "struggle for life as it historically presents itself in various determinate forms of society," that, in the current fashion of thought, "one has nothing to do but to turn every concrete struggle into the phrase 'struggle for life' and to translate the phrase into the Malthusian population fantasy."²⁶

Both Malthus and Marx comment on the family and marriage. Malthus recognized that society is exposed to vice, whether it arises from prudential restraint or from the squalid poverty generated by overpopulation. Moral restraint is his remedy. Even women would benefit by postponing the age of marriage. "If the general age of marriage among women were later," he averred, "the period of youth and hope would be prolonged and fewer would be ultimately disappointed." The Marxian remedy is the radical one of abolishing the present system of production.

Marx's conceptions were no doubt affected by a recognition of the growing economic importance of women. This item is inconsequential in the Malthusian treatise.²⁷ But Marx comments on the growing substitution of female for male labor, on the induction of mothers into industrial employment, and on the consequent need to hire substitutes for the home and to replace domestic work by ready-made products. The process develops as a sort of social catalysis that leads to a dissolution of family life, excessive mortality rates among the children of workers, the disruption of family ties, and the transforming of children into instruments of labor. But there is a constructive side. The part played by women, young

²⁵ Darwin, *The Origin of Species* (D. Appleton and Co., 1925), p. 60.

²⁶ Marx, Letter to Kugelman, June 27, 1870.

²⁷ Malthus had stated (Everyman's Library, II: 19) that "It could not be expected that women should have resources sufficient to support their own children."

persons, and children in the socially organized process of production, he writes, "is building the new economic foundation for a higher form of the family and of the relation between the sexes."

Marx's ideas on population are a reflection of his wider thoughts on the subject of capital. It is to be noted that he deliberately circumscribed his field by proposing a law of population effective in the present historic mode of production, in place of a natural law applicable to all periods of human existence and to every form of social organization. Nor did Marx find it necessary to center his discussion on the working out of a system of natural checks. Thus he gives only fleeting notice to a subject that Malthus deals with in twenty-one chapters: the actual operation of the checks in society, from ancient times to the present; in the islands of the South Sea, in different parts of Africa, in Switzerland, France, England, and other countries. The Marxian thesis, being but a detail in the completed pattern of his critique of capitalism, is not given the commanding position that Malthus gives to the subject. It is not used as a frame of reference for adjudicating various moot issues in the political and economic fields. Nor is it a point of departure for an understanding of "the causes that have hitherto impeded the progress of mankind toward happiness." It is an exposition of the problem of the changing numbers of the laboring classes, so far as this problem is related to the main tools of his analysis, e.g. capitalistic accumulation, surplus value, and the increased use of constant capital in modern industry.

Though Marx did not ignore natural increase, he bore down with special zest on what he regarded as the really important issue in the light of actual experience, the labor reserve. This approach necessitated the consideration of the varied factors of supply. There was, of course, the natural increase stimulated by the abnormal, misery-engendering environment of the proletariat. But there were divers other influences independent of the instinct of propagation: the depreciation of labor by machinery; the substitution of women and children for adult, male labor; the intensification of work; the absorption into the proletariat of the lower strata of the middle class; the intrusion of capitalistic methods into agriculture;²⁸ the age

²⁸ The effect of the subjection of agriculture to capitalist production is that the demand for an agricultural laboring population falls absolutely without the loss being compensated later by a greater attraction. Marx, *op. cit.*, I: 705.

factor, and "incapacity for adaptation, due to the division of labor." If, as Keynes points out, Malthus' stress in the later editions of the *Essay on Population* "is on the importance of labor curtailing its supply," this is the answer. Though not invulnerable to criticism, it is at least challenging. Conjoined with other elements of the Marxian interpretation, it injects new and unconventional ideas into the field of population analysis.

WAYNE UNIVERSITY
DETROIT, MICHIGAN

A DECADE AND A HALF OF AMERICAN AGRICULTURAL POLICY

HARALD S. PATTON

IN NO other period in history has the intervention of national governments relative to agriculture been applied so universally and to so far-reaching an extent as during the past half-dozen years. Although 1933 marked the lowest point in agricultural prices and international trade, the succeeding years have witnessed a multiplication and an intensification of governmental controls over national agricultural economies. What were first undertaken as emergency relief measures, under the stress of the world agricultural depression, are being converted into more or less consciously conceived programs of national agricultural planning.

In this world-wide movement we find engaged, not only such a state as Soviet Russia, with its agricultural collectivization program and government monopoly of foreign trade, but also England, the traditional home of agricultural *laissez faire*; not only the war-fevered nations of continental Europe, but also the freer-breathing countries of Latin America and the British dominions. In food-deficit nations government policy takes the form of subsidizing farmers for expanding acreage and increasing domestic production. In agricultural-surplus countries governments pay bounties for curtailing acreage and reducing production. The same country may be found subsidizing exports of certain products and imposing import quotas and antidumping penalties on other products.

Although this paper is confined mainly to considerations of recent agricultural policy and planning in the United States, such policy must be conceived of as a shifting adjustment to a changed international economy. It is merely one national segment in a world of agricultural controls. Our agricultural adjustment program differed from governmental measures elsewhere, not in the extent of the controls it established, but rather in the relative belatedness of its introduction, in the greater area over which it was applied, and in

expressing the policy of the one country in the world which is both a creditor nation and a major agricultural exporting nation.

THE POSTWAR DISEQUILIBRIUM IN AMERICAN AGRICULTURE

The course of farm-relief legislation during the past decade and a half and the evolution of agricultural planning in the United States have their roots in the disequilibrium in the American agricultural economy arising out of the World War. It abruptly reversed a tendency apparent after about 1897 toward a gradual decline in the volume of agricultural exports, both absolutely and in relation to total production. This was a normal reflection of rising population and industrialization, and of the passing of free, productive land. Crop land per capita reached its peak in 1900, and the number of livestock per capita began to decline after 1894. The average acreage devoted to production for export during the five years preceding the World War was only 80 per cent of that for the period 1899-1903.

The war period, under the triple stimulus of soaring prices, patriotic "food-will-win-the-war" appeals, and huge government credits to our European allies, brought about an addition of some 40 million acres to the nation's crop area. Wheat acreage alone jumped from 50 million acres in 1913 to 73 million in 1919. Excluding cotton (exports of which declined heavily under reduced textile consumption abroad) the physical volume of United States agricultural exports in 1918-19 was 155 per cent greater than in 1910-14. With Europe's crop acreage 82 million less in 1920 than in prewar years, and with Russia, formerly the chief supplier of the food deficiencies of northwestern Europe, eliminated as an agricultural exporter, overseas supplies were urgently needed for some years after the Armistice — a requirement which the extension of United States government postarmistice credits to foreign countries, to the amount of some three and one-quarter billion dollars, helped to meet. Up to 1923 the volume of American agricultural exports (excluding cotton) remained at more than double the prewar average. The average acreage devoted to export production during the four postwar years (1919-22) was in fact 40 per cent greater than that for the five years preceding the war.

The war profoundly affected American agriculture in another way, by compressing into the span of a few years the conversion of the United States from the status of an international debtor to that

of a creditor nation. This meant that American agricultural export trade was stimulated at a time when it was no longer needed to meet a national external debt service. It meant, furthermore, that the continuance of large-scale exports was dependent on the continuance of American lending abroad. The great outflow of American private capital between 1925 and 1928 served indeed to sustain the outward movement of our agricultural products during the later 'twenties, the total volume remaining above the prewar level until 1929.

This artificial support afforded by New York underwriters of foreign securities served to postpone and eventually to render more distressing to American farmers an adjustment in acreage for export production which the international agricultural situation indicated to the discerning. By 1928 agricultural production in the formerly belligerent countries of northwestern and central Europe had regained its prewar level, and Russia and the Danubian countries were reappearing as agricultural exporters. This implied a gradual disappearance of wartime dependence on overseas supplies and a return toward the pattern of prewar European agricultural commerce. As François Delaisi points out in his *Les Deux Europes*, continental Europe as a whole is normally agriculturally self-sufficient, except with respect to cotton and tropical products. Furthermore, the war and the postwar capital movements had stimulated agricultural production for export in Canada and Southern Hemisphere countries to an even greater extent than in the United States. Hence, after 1923 American exports of grains, and milling, packing-house, and dairy products declined sharply, and although exports of cotton, tobacco, and fruits increased in volume during the cyclical uplift of the late 'twenties, price returns to producers generally bore an unfavorable relation to prevailing costs and debt charges based on wartime capitalizations.

Whether one accepts the agricultural overproduction thesis of Timoshenko,¹ or the gold-price theory of Warren and Pearson,² as the fundamental explanation of the world agricultural depression, it is clear that the export branches of American agriculture were in a highly vulnerable position in the late 'twenties; and that the maintenance of the war-stimulated expansion of crop acreage long after

¹ Timoshenko, Vladimir, "World Agriculture and the Depression," *Michigan Business Studies*, Vol. 5, No. 5 (Ann Arbor, 1933).

² Warren, George F., and Pearson, Frank A., *Prices* (New York, 1933).

the foreign demand for its surplus production had eased off or been made ineffective was indicative of a serious disequilibrium in the American agricultural economy.

PRE-NEW DEAL AGRICULTURAL POLICIES

I have stressed the effects of the war on American agriculture because they have lain at the roots of the difficulties of the export branches ever since 1923 and because they afford the clue to all the relief measures and adjustment programs of the last decade and a half. The practical problem for every administration since Wilson's has been to shelter that branch of the American economy which is least organized industrially and most exposed to the risks and stress of international competition, and to bring it within the scope of the American protective and price system.

Harding and Coolidge relied chiefly on the traditional Republican instrumentality of the tariff as the agency of protection and of adjustment as well. Easterners both, they counseled the producers of surplus crops to shift to the production of commodities for which the nation was on a deficit basis and on which the tariff would be effective at whatever level necessary to protect the home market. Traditional regional production patterns are not readily changed, however, by individual farmers, no matter how high the source of exhortation, and out of the Corn Belt came two rival schemes for making the tariff effective on surplus products: The equalization-fee plan and the export debenture plan. The former, of which Hugh Johnson and George N. Peek (then associated with the Moline Plow Company) were the joint authors, contemplated the application to the agricultural export industries of the technique of German industrial cartels, whereby exports have been subsidized through small assessments on each unit marketed by cartel members. The Moline proposal, congressionally drafted as the McNary-Haugen Bill, sought to break the price dependence of agricultural export products upon international supply-and-demand conditions by moving into export channels such surpluses as would permit the maintenance of tariff-enhanced prices upon domestic markets, losses on export sales being covered by small equalization fees levied on each unit marketed or processed.

The export debenture plan, based upon the German import certificate (*Einfuhrschein*) system and sponsored by the National Grange,

would have entitled exporters of designated agricultural products, in crude or processed form, to receive so-called negotiable debentures having a value for customs payment purposes equivalent to half the tariff duty on each unit of the primary product entering into export. The plan contemplated, therefore, a diversion of what would otherwise have been customs revenue into a bonus for exporters, who would be expected to be in a position to pay higher prices to farm producers of the commodities concerned.

Both these plans sought to make the tariff effective on surplus farm products and by indirect means to lift the domestic price above the world competitive level, at the expense of consumers or tax payers. Bills embodying these were thrice killed by presidential vetoes, mainly on the declared ground that to the extent that they might be successful in price elevation they would serve to stimulate greater production of surplus products and thus aggravate the basic maladjustment in the American agricultural economy.

The Agricultural Marketing Act of 1929 — President Hoover's companion piece to the exalted agricultural schedule in the Hawley-Smoot Tariff Act — embodied most of the provisions of the later Congressional versions of the McNary-Haugen plan, except its distinctive equalization-fee feature. A Federal Farm Board, with its half-billion-dollar revolving loan fund, its commodity advisory councils, its loans to nationally organized coöperatives and emergency stabilization corporations — all these were features common to both measures. The Farm Board Act thus sought to increase farmers' returns through creating a nation-wide producer-controlled, but government-financed, commodity-marketing machinery which it was hoped, in the language of the act, might "stabilize the currents of interstate and foreign commerce in the marketing of agricultural products." The Farm Board had hardly been created before prices of agricultural staples in world markets entered upon the first abrupt descent that eventually carried most of them to the lowest levels in trade history. Under these conditions the emergency stabilization provisions of the act were invoked with respect to wheat and cotton. During the accumulation phase of the cash and future holdings of the grain- and cotton-stabilization corporations, domestic prices were substantially lifted above world competitive levels, but exports themselves were dammed back, and the Farm Board entered its fourth year with holdings of, or loan commitments on, 108 million bushels

of wheat and over 3 million bales of cotton. Its operations had cushioned the shock of catastrophic deflation for farmers, middlemen, processors, and their bank creditors. But the enforced cessation of its market support, as its revolving fund became depleted or immobilized, made the problem of eventual liquidation all the more formidable.

Fervid appeals carried by Board members to producers in the wheat and cotton states to curtail their acreage proved of slight avail. The harvested wheat acreage in 1932, despite some reduction from the 1930 level of 62,600,000 acres, was still greater than that of 1926; cotton acreage under cultivation in 1933 was $4\frac{1}{2}$ million above that of 1932; while the harvested acreage of corn in 1932 was more than 10 million greater than in 1929. This situation demonstrated the fact that farmers, when burdened by fixed debt and tax charges and falling prices for their products, are under pressure, as individuals, to increase their cash income and to reduce unit costs by expanding the output of the farm plant. The Farm Board, in its second annual report, recognized the futility of its task in these significant observations:

If producers fail or are unable to readjust production in the light of the economic outlook, stabilization can only hold back, rather than hasten the needed adjustments. . . . It is without effect to make appeals on what American farming might do if it were all organized as a single unit, for it is not so organized. Until farmers are organized for production planning it is useless to expect them to act as if they were.

THE AGRICULTURAL ADJUSTMENT PROGRAM

This epitaph of the Federal Farm Board may be regarded as the birth notice of the New Deal agricultural adjustment program. Assuming a direct commodity attack — in contrast to, or rather in conjunction with, the indirect general price-level attack through the Government's gold policy — the AAA sought to elevate market prices through acreage reduction in "basic commodities" and to compensate farmers for curtailed volume by substantial contractual benefit payments. As the first administrator, G. N. Peek, put it, the program involved an attack "at the grass roots." Despite its voluntary character and its administrative difficulties it did prove effective in procuring some 3,700,000 production-control contracts by the end of 1934, and in bringing about a net reduction of some 34 million acres in the area planted to wheat, corn, cotton, and tobacco. The

world carry-over of American cotton, which amounted to the record figure of 12,960,000 bales on August 1, 1932, had been reduced to 9,000,000 bales at the beginning of the 1935 harvest. Stocks of American wheat, which stood at 360,000,000 bushels on July 1, 1932, had been brought down, through acreage reduction and drought, to a normal level of 157,000,000 bushels by July, 1935. Under the joint influence of adjustment programs, dollar devaluation, drought, and industrial recovery the combined index of prices received by farmers for their products rose from 55 per cent of the prewar (1909-14) average in March, 1933, to 111 per cent in February, 1935, thus doubling within two years. The price index number of cotton and cottonseed in January, 1936, was 214 per cent of the 1933 low, and that of the grains group 255 per cent. The declared objective of restoring the purchasing power of farm products to their prewar parity, of which the index in March, 1933, was only 55 per cent, has been realized to the extent of 89 per cent of the goal. It would thus appear that, so far as the rehabilitation of American agriculture is a matter of surplus elimination, retirement of acreage for export production, and price restoration, the basic adjustment has been substantially achieved.

While the agricultural adjustment program has been only one factor, and perhaps not the major factor, in this accomplishment, the administration of this particular form of agricultural planning has given rise to new problems and created or called attention to other maladjustments in the agricultural economy. Certain lessons may be drawn from AAA experience which have a significant relation to the newly promulgated substitute measure, the Soil Conservation and Domestic Allotment Act.

THE EXPERIENCE IN PRODUCTION CONTROL

Although the generous scale of benefit and rental payments offered under the various adjustment programs for "basic commodities" was effective in winning the participation of a remarkably high percentage of producers and acreage (especially of cotton and tobacco), the voluntary nature of the plan involved the likelihood that any resulting price advance would serve to stimulate increased planting or intensification of cultivation by noncontracting producers. In fact, while the first wheat "sign-up" campaign resulted in 12 per cent of the base acreage being contracted out of cultivation, the net

reduction proved to be only 8 per cent. It was experience of this tendency that led to the passing in 1934 of the compulsory Bankhead Cotton Control Act and the Kerr-Smith Tobacco Control Act, under which maximum tax-free marketing quotas were established for all producers, deliveries not accompanied by such tax-exemption certificates being subject to high penalty taxes. The same principle was applied in the more drastic Warren Potato Marketing Act of 1935, in which the penalty system was unaccompanied by benefit payments. Here was demonstrated the tendency for voluntary schemes to be converted into compulsory plans. All three of these measures were revoked by the President after the Hoosac Mills decision of the Supreme Court.

A second lesson from AAA experience has been that acreage control, however inclusive, does not in itself assure control of supply. Not only may cultivation be intensified on reduced acreage (the poorer-yielding acres being those most likely to be retired), but uncontrollable Nature exercised a dominating hand in yield determination. The AAA, for example, "planned" a wheat crop in 1934 of 775 million bushels, based on "average yields." The drought reduced the yield to less than 500 million bushels, and resulted in a net import of wheat in the ensuing twelve months. The AAA reacted to the drought situation by removing restrictions on fall wheat plantings and in the 1936 wheat contracts agreed to continue benefits to farmers who did not *exceed* their base acreage. Incidentally, AAA contracts proved a form of crop insurance to drought-stricken farmers, since they received their benefit payments even though they had no crop to market. The drought experience served, however, to emphasize the social utility of surplus stocks of agricultural products as emergency reserves for the nation, and was reflected in Secretary Wallace's "ever-normal granary plan," which contemplated the making of loans to producers on surplus stocks held in sealed granaries or in warehouses, with the assurance that any advance in market value under short-crop conditions would accrue to the producer as equity holder.

A manifest defect of the AAA production-control plan lay in the blanket character of at least its earlier reduction contracts. The same percentage of reduction from base acreage was called for, regardless of the location or the fertility of the land, of whether the crop in question was a single crop or a rotation crop, of whether

it was grown in a high-cost or a low-cost area, of whether the producer was an owner, a tenant, or a share-cropper. While this feature was perhaps inevitable in an emergency program, it was in itself inconsistent with the idea of true adjustment, since it served to "freeze" past land-utilization records as a vested interest and failed to discriminate between farmers who had already made adjustments and those who persisted in single-cropping practices. AAA leaders have been quite aware of this defect, and later contracts have provided for more flexible bases and optional benefit plans. This very effort, however, to "adjust adjustment" served to make administration almost hopelessly complicated.

A further lesson from AAA experience has been its effect on American agricultural export trade. Its very success in elevating prices has reacted adversely to such trade, despite the cheapening of the dollar in terms of foreign currencies. Cotton exports, which averaged 8,730,000 bales in 1932 and 1933, during the depth of the depression, have been reduced to an average of only 5,800,000 annually during the two full years of AAA activity, 1934 and 1935. While the shrinkage in 1934 is partly accounted for by the previous accumulations of American cotton stocks abroad, this country's relative share of world cotton export trade has declined significantly. It is interesting to observe that, though the United States is subsidizing the diversion of cotton acreage to other uses, Brazil and Argentina are seeking to diversify their respective agricultures by encouraging cotton growing, and Liverpool has introduced a cotton-futures contract permitting deliveries of Brazilian and Argentine cotton. American exports of leaf tobacco in 1935 amounted to 381 million pounds, compared to an average of 532 million pounds in 1930-31. Exports of lard were only a twelfth of what they had been in 1932 and 1933, while wheat has been on a net import basis during the last two years. Such exports of American wheat and flour as have moved out have for the most part been made possible only by virtue of export bounties under the Portland Wheat Agreement, involving an average subsidy to exporters of 23 cents a bushel derived from processing tax funds. It is significant that the amendments last year to the Agricultural Adjustment Act included a provision authorizing the employment of up to 30 per cent of customs revenue for the purpose (in part) of encouraging the exportation of agricultural products by indemnifying exporters for losses incurred therein. Here we find

the principle of the export debenture plan grafted upon the Agricultural Adjustment Act.

FROM EMERGENCY ADJUSTMENT TO LONG-TIME PLANNING

Although the invalidation by the Supreme Court of the tax-supported production-control features of the Agricultural Adjustment Act was based on constitutional rather than on economic considerations, and although its rulings further upset the administration's budgetary calculation, the action of the nation's high tribunal was both timely and in the best interests of national agricultural planning itself. The Adjustment Act of 1933, reinforced by the great drought of 1934, had essentially accomplished its emergency purpose of surplus removal and farm price restoration. Processing taxes for benefit payments to farmers, when farm prices were palpably below the deflated production costs of even efficient producers, had a substantial measure of social justification. The restoration of farm-purchasing, debt-, and tax-paying power was in the interests of farm creditors, industry, and local governments, as well as of farm families themselves. But continuance of such taxes, with parity levels substantially restored, in order to finance contractual payments, involved a burden on consumers no longer warranted by the price situation. It was a burden, moreover, which fell to a considerable extent on agriculture itself, for farmers, it is estimated, are themselves the consumers of about 40 per cent of what is produced on the nation's farms. As noted above, the adjustment program was inducing new maladjustments and becoming administratively unworkable, and AAA leaders were themselves moving toward a simpler, more permanent, and more economically justifiable plan. The Supreme Court, therefore, rendered a service to all concerned, in sweeping away at a judicial stroke the tax and commodity contract structure, instead of leaving the act to piecemeal Congressional amendment and compromise.

Although the substitute Soil Conservation and Domestic Allotment Act has been characterized as an ingenious device for continuing benefit payments to farmers and for perpetuating the AAA bureaucracy, it is by no means an impromptu measure, but represents rather the crystallization of plans which had been shaping for some time in the Land Planning Division of the AAA. It is instructive to note the shifts in policy, emphasis, and method between the acts of 1933 and 1936.

1. From surplus removal to "balanced abundance"

The immediate problem confronting the AAA in 1933 was the elimination of price-devastating surpluses. Hence the first crude cotton "plow-up" campaign and pig massacres, and the concentration on acreage retirement. The great drought, consumer complaints, and mounting agricultural imports (food imports in 1935 were nearly three times the value of food exports) compelled realization of the social utility of adequate food and feed reserves. Thus in the declaratory section of the new act it is stated significantly that "due regard shall be given to the maintenance of a continuous and stable supply of agricultural products adequate to meet consumer demand at prices fair to both producers and consumers, and the powers conferred upon the Secretary of Agriculture shall not be used to discourage the production of supplies of food and fibers sufficient to maintain normal domestic human consumption," as based on the period 1920-29. Here is to be discerned a shift from the economy of scarcity to the economy of balanced abundance.

2. From acreage retirement to soil conservation

It was recognized by AAA leaders at the outset that retirement of acreage from surplus crops must be accompanied by some control over the use of such "contracted" acreage, lest it lead to the "unbalancing" of some other crop. Hence the first wheat and corn contracts stipulated that such land could be used only "for planting additional permanent pasture; for soil-improving and erosion-preventing crops not to be harvested; resting or fallowing the land; for weed eradication; or for planting farm woodlots." The cotton and tobacco contracts, in the interests of greater diversification and higher living standards for Southern cultivators, also permitted the use of contracted acreage for food and feed crops for home consumption. The Replacement Crops Section of AAA estimated, on the basis of cross-section surveys, that of the 30 million acres withdrawn from basic crop reduction in 1934 about one third were put into pasture or meadow crops; another third used for drought emergency forage crops, or for food and feed crops for home use; and the remainder either planted to farm woodlots, fallowed, or left idle.

The devastating drought and dust storms of 1934 and the revelations of the newly created Soil Erosion Service (which estimates that 50 million acres have been permanently ruined for crop use by water and wind erosion, with another 50 million acres approaching that condition) have been perhaps timely reminders that crop surpluses are not the greatest evil affecting American agriculture. Along with this has come a new appreciation of Henry Carey's warning that a nation specializing in the exportation of cash crops is, in effect, exporting its soil fertility. When export prices become conspicuously unremunerative, there no longer exists even a pecuniary compensation to the farmer for such depletion of his soil resources.

Under the new act the replacement crops program, which had hitherto been merely incidental to acreage retirement, now becomes the major objective. The declared policy is restated as "the preservation and improvement of soil fertility; the promotion of the economic use and conservation of land; the diminution of exploitation and wasteful and unscientific use of national soil resources." Farmers are henceforth to be compensated, not directly for the crop land they retire, but for the acreage they add in the form of soil-restoring pasture, leguminous crops, woodlots, etc., and for other approved practices in the interests of conservation.

3. From commodity control to regional land-use adjustment

The 1933 act had listed seven "basic commodities" to which adjustment contracts and benefit payments might be applied, namely, wheat, cotton, corn, hogs, tobacco, rice, and milk and its products. Sectional interests, fears that retirement of land from production of these commodities would lead to expanded output of other products, and demands to extend the scope of benefit payments had led to the addition, through successive amendments of the act, of ten other products (including such items as peanuts and grain sorghums) to the list of so-called basic commodities. This meant that the same farmer might be a signatory to a plurality of contracts, answerable to various county allotment committees and AAA commodity sections. Apart from the administrative complications, the system involved an unbalancing of individual farm enterprises and regional dislocations. For a year or more before the Supreme Court ruling AAA officials had been working on a plan of blanket contracts covering a farmer's total crop acreage and had

already moved toward a program of setting up continuing county agricultural adjustment planning committees composed of farmers. The new act and the administrative steps so far taken thereunder are in accordance with this more inclusive and permanent plan. The country has been zoned into five major agricultural regions, and the former directors of commodity divisions have been converted into regional directors. Preliminary regional conferences point to a program under which the ratio that each participating farmer's acreage in "soil-depleting crops" bears to his acreage in pasture and "soil-conserving crops" will be compared with a regionally determined base. To the extent that he changes his farm management practices to increase the proportion of the latter, or to the extent that he already exceeds the base ratio, he is to share in the new scale of benefit payments. Performance will thus be gauged, not in terms of retirement of acreage from specific crop use, but in terms of good farm-management practice as determined for the farmer's particular area. Here is to be discerned a return to the original purposes of the United States Department of Agriculture and the land-grant colleges, but with the added features of established "yardsticks" of performance and of pecuniary reward.

4. From centralization to state and local coöperation

The Supreme Court's finding that the Agricultural Adjustment Act involved an unwarranted invasion of state rights and powers by the federal authority has made obligatory and immediate a shift in federal-state administrative relations toward which the adjustment program was already tending in spirit, consultation, and coöperation. In contrast to the industrial recovery program, for which an independent administration had to be hastily improvised *de novo*, the agricultural recovery program had the conspicuous advantage of being fitted into the existing system of coöperating agricultural agencies, extending from the bureaus of the United States Department of Agriculture through the forty-eight state land-grant colleges, with their federally subsidized experiment stations and extension divisions, out to the army of county agricultural agents contacting farmers directly throughout the nation. The Supreme Court verdict has, therefore, created no such chaos in the agricultural adjustment program as it did with respect to NRA. It has merely involved a shift in the relationship of federal and state agencies.

Direct contracts between farmers and the Secretary of Agriculture now give place to applications by farmers to become members of county soil-conservation associations, and direct AAA benefit checks to contract signers are replaced by federal allotments to states, financed by general taxes, and distributed to farmers through the appropriate state agencies, on the basis of land-use performance in accordance with locally established and federally approved standards. This transitional arrangement is to continue to the end of 1937, after which federal grants will be made only to states which submit programs of their own that are approved by the Secretary of Agriculture as in accordance with the act.

The new act, it thus appears, is not a mere circumvention of the Supreme Court's arbitrament, but represents, significantly, a definite transition from an emergency program to a more permanent program of national agricultural planning. It embodies a realization that nature as well as markets has to be reckoned with, and that good farming and scientific use of land afford the best assurances of enduring agricultural prosperity in a nation. But it also recognizes that individual farmers, burdened by debt and confronted with low prices, are under pressure to exploit their soil, since they lack the resources, even if they possessed the knowledge and the desire, to finance the necessary changes in farm practice and to await the deferred returns from diverting cash-crop land into soil-preserving uses. Hence the provision for benefit payments to compensate farmers for the additional costs involved in such transition and for foregoing the cash returns that might be realized from continued cropping. An obvious problem arises, however, in the dispensation of these payments. They are most necessary, perhaps, in those areas where water and wind erosion have wrought the greatest havoc, where soil practice has been most wasteful, and where crops have been chiefly produced for an export market that appears to have definitely contracted. On the other hand, those states whose agriculture is on a domestic basis and in which more balanced, scientific farming practices prevail are not disposed to forego their share of federal benefits. Thus the preliminary regional conferences point to a plan under which a higher scale of benefits will be paid to farmers who raise the ratio of their land in pasture and leguminous crops toward the locally established level, and a smaller range of payments for those who already exceed such per-

centage. Sectional conflicts will undoubtedly arise on this issue, and much ingenuity and compromise will be needed to devise workable formulas for different states and localities.

Despite certain manifest defects and limitations the agricultural adjustment programs have eased and aided the fundamental and long-overdue adjustment which the upheaval induced by the World War had called for and which the world depression made imperative. They have helped American farmers to coöperate both industrially and regionally in a changing economic society wherein agriculture had become almost the sole remaining sphere in which individualism and unregulated competition held sway. In the future foreign trade may be expected to play a smaller part relatively in the American agricultural economy, and it will probably continue to be accompanied by some application of export bounties and import quotas in the interests of price stability. Direct benefit payments should disappear as adjustment proceeds, but planned marketing, planned production, and planned land use are developments to which the events of the last decade and a half, as reviewed above, appear to give institutional significance. And in this more balanced arrangement the interests of agriculture need not be at variance with the interests of society at large.

MICHIGAN STATE COLLEGE
EAST LANSING, MICHIGAN

SOME RESUPINATE POLYPORES FROM THE REGION OF THE GREAT LAKES. VIII

DOW V. BAXTER

THE title of this series of papers implies that the monographs are written primarily on material within the confines of the region of the Great Lakes. The design for the study, however, has been to formulate as complete a record of the group as is feasible at this time. This necessitates, therefore, a study of material from all possible forest types from other regions of the continent as well as from the timberlands within the country bordering the Great Lakes. Many of these collections from North America have been compared with type specimens here and also with those found in the larger herbaria of Europe.¹

Descriptions of six resupinate species are presented in this paper and, in addition, the characteristics of nineteen brown polypores in culture are discussed. The majority of these plants were collected over a wide territory, ranging from the white spruce forests of interior Alaska and the Yukon to the hardwoods of Georgia, South Carolina, and Florida. Cultures obtained from the same fungi on many different woods and ranges offer opportunity to compare the varying effects of geographical distribution and substrata upon the growth of the plants. Rate of growth and other differences in culture are to be observed in some of these. The following resupinate polypores, the majority of which are reported in culture for the first time, are added to this study:²

¹ Throughout the work upon these monographic studies I am indebted to many individuals and institutions for help, suggestions, and privileges extended to me. My appreciation is expressed particularly to Professors T. G. Halle and Gunnar Samuelson of the Naturhistoriska Riksmuséet in Stockholm, with whom I have had the pleasure of association. I am under obligation to several American institutions and scholars also; to the authorities at the New York Botanical Garden and to those of the Division of Pathological Collections of the United States Department of Agriculture I am particularly indebted.

² The terms used in this classification are defined in Papers V-VI of this series, as cited at the end of this article.

A. RATE OF GROWTH

Rapid growth

- | | |
|---|--|
| <i>Polyporus glomeratus?</i> on <i>Quercus laurifolia</i> from Ocala National Forest, Florida | <i>Poria ambigua</i> on <i>Nyssa biflora</i> from Stark, Florida |
|---|--|

Slow growth

- | | |
|---|---|
| <i>Fomitiporia flavomarginata</i> , Strain E, on <i>Quercus nigra</i> from Walterboro, South Carolina | <i>Fomitiporia Earleae</i> , Strain II, on <i>Liquidambar styraciflua</i> from Kingsland, Georgia |
| <i>Poria punctata</i> on <i>Rhus vernix</i> from Whitmore Lake, Michigan | <i>Fomitiporia dryophila</i> on <i>Quercus sp.</i> from Ocala National Forest, Florida |
| <i>Fomitiporia Earleae</i> , Strain I, on <i>Nyssa biflora</i> from Osceola National Forest, Florida | |

B. RANGE OF TEMPERATURE FOR GROWTH

Large range

- | | |
|---|---|
| <i>Polyporus glomeratus?</i> on <i>Quercus laurifolia</i> from Ocala National Forest, Florida | <i>Fomitiporia Earleae</i> , Strain II, on <i>Liquidambar styraciflua</i> from Kingsland, Georgia |
| <i>Fomitiporia flavomarginata</i> , Strain E, on <i>Quercus nigra</i> from Walterboro, South Carolina | <i>Fomitiporia dryophila</i> on <i>Quercus sp.</i> from Ocala National Forest, Florida |
| <i>Poria punctata</i> on <i>Rhus vernix</i> from Whitmore Lake, Michigan | <i>Poria ambigua</i> on <i>Nyssa biflora</i> from Stark, Florida |
| <i>Fomitiporia Earleae</i> , Strain I, on <i>Nyssa biflora</i> from Osceola National Forest, Florida | |

C. TEMPERATURE FOR BEST GROWTH

High temperature

- | | |
|---|---|
| <i>Fomitiporia Earleae</i> , Strain II, on <i>Liquidambar styraciflua</i> from Kingsland, Georgia | <i>Polyporus glomeratus?</i> on <i>Quercus laurifolia</i> from Ocala National Forest, Florida |
| <i>Fomitiporia dryophila</i> on <i>Quercus sp.</i> from Ocala National Forest, Florida | <i>Poria ambigua</i> on <i>Nyssa biflora</i> from Stark, Florida |
| <i>Fomitiporia flavomarginata</i> , Strain E, on <i>Quercus nigra</i> from Walterboro, South Carolina | |

Average temperature

- Poria punctata* on *Rhus vernix* from Whitmore Lake, Michigan

D. EFFECT OF LIGHT

Best growth in dark

<i>Fomitiporia dryophila</i> on <i>Quercus</i> sp. from Ocala National Forest, Florida	<i>Poria punctata</i> on <i>Rhus vernix</i> from Whitmore Lake, Michigan
<i>Fomitiporia Earleae</i> , Strain I, on <i>Nyssa</i> <i>biflora</i> from Osceola National Forest, Florida	<i>Polyporus glomeratus?</i> on <i>Quercus lauri-</i> <i>folia</i> from Ocala National Forest, Florida
<i>Fomitiporia Earleae</i> , Strain II, on <i>Liquidambar styraciflua</i> from Kings- land, Georgia	<i>Fomitiporia flavomarginata</i> , Strain E, on <i>Quercus nigra</i> Walterboro, South Carolina

Equal growth in light and dark

<i>Poria ambigua</i> on <i>Nyssa biflora</i> from Stark, Florida

Data on color characteristics, texture, effect upon the agar medium, and the rate of growth in the light and the dark have already been presented for many resupinate polypores in this series of papers (1-3). The problem of distinguishing the resupinate polypores in culture becomes complex, however, because the features described for young cultures change with age. In fact, many distinctive growth forms appear in thirty-five-week-old liter flask cultures, but do not appear at all when the fungus is grown in small tubes or petri dishes for short periods of one or two or even four weeks. For this reason, descriptions of old liter-flask cultures are to be presented with the species described. These may be contrasted with those presented for the two-week-old cultures recorded in Table I. Differences in age, temperature, type, and amount of substrata, moisture, and light can produce variations in cultures of these resupinate polypores that are just as significant and confusing as those changes which are caused in the fruit bodies themselves by modified natural environments. (See Pls. XXXI-XXXII.) Furthermore, it is believed that, when a large number of cultures of many species are compared, broad lines of distinction between certain species and groups of other species can be observed. The growth features of nineteen additional plants are presented in Table I. Though such variations complicate the possibilities of determining with accuracy the identity of the causal organism for certain rots when the mycelium is isolated from wood, it is held that characters obtained in culture can be used as supplementary to the morphological features of the fruiting body itself.

TABLE I
GROWTH CHARACTERISTICS OF BROWN POLYPORES ON MALT AGAR

NAME	IN LIGHT						IN DARK				
	Rate in mm. 2 weeks	Color (Ridgway)	Texture and form	Character of margin	Agar discoloration	Pore formation	Rate in mm. 2 weeks	Color (Ridgway)	Texture and form	Agar discoloration	Pore formation
<i>P. ferrea</i> on <i>Abies</i> sp. from Foster, Oregon	17.8	Clay color to Sayal brown	Cottony Radiating	Definite Fibrous	None	None	23.3	White to cinnamon-buff to Sayal brown	Cottony Radiating Slightly nodulose	None	None
<i>P. ferrea</i> on <i>Thuja plicata</i> from Oregon	20.8	Cinnamon-buff to cinnamon	Cottony	Definite or indefinite Fibrous	None, but pore formation in two-month-old culture	None	31.5	Cinnamon	Cottony Radiating	None	None
<i>P. ferrea</i> on <i>A. macrophyllum</i> from Oregon	19.7	Clay color to Sayal brown	Cottony Radiating to radiating fans	White Definite Fibrous	None	None	25.4	White (not only margin) to cinnamon-buff to Sayal brown	Cottony Radiating	None	None
<i>P. ferrea</i> on <i>Santaliz</i> sp. from Oregon	16.8	Clay color to Sayal brown	Cottony Radiating to radiating fans	White Definite Fibrous	None	None	25.6	White (not only margin) to cinnamon-buff to clay color	Cottony Radiating Few exudations	None	None
<i>Pol. glomeratus?</i> on <i>Q. laurifolia</i> from Ocala National Forest, Florida	...	Cream-buff to snuff-brown	Cottony Concentric ring growth	Indefinite Silky	None	None	...	Naples yellow to chamois to honey-yellow	Cottony Exudations	None	None
<i>P. tsugina</i> (13W) on <i>T. heterophylla</i> from Vancouver, British Columbia	10.3	Chamois	Chamois Exudations	Definite or indefinite Silky	None, but discoloration appearing in older cultures	None in these cultures, but pores formed in 3½ months at 10° C.	15.5	Chamois to Isabella color	Chamois	None	None

<i>P. tsugina</i> (14W) on <i>T. hetero-</i> <i>phylla</i> from Vancouver, British Co- lumbia	5.4	Cream-buff to straw- to yellow to amber-yel- low	Cottony	Indefinite Silky	None	None	None	Deep colo- rial buff to primuline yellow	Cottony	None	None
<i>P. tsugina</i> on <i>T.</i> <i>canadensis</i> from Mar- quette, Michi- gan	7.6	Yellow other to primu- line yellow	Chamois Concentric- ring growth	Definite Silky	None	None	None	Cream-buff	Border fibrous	None	None
<i>F. nigrolimitatus</i> on <i>T. hetero-</i> <i>phylla</i> from Wrangell, Alaska	17.0	Chamois to tawny	Chamois to slightly cottony Radiating	Indefinite Silky	None	None	None	(White mar- gin) Cream-buff to cinna- mon	Slightly cot- tony Radiating	None	None
<i>F. nigrolimitatus</i> on <i>T. hetero-</i> <i>phylla</i> from Tyee, Alaska	21.0	Clay color to cinnamon- brown to amber- brown	Not radiat- ing	Definite or indefinite Fibrous	None	None	None	(White mar- gin) Cream color to cinna- mon	Chamois to slightly cottony Radiating	None	None
<i>T. odorata</i> on <i>Pinus resinosa</i> from Shell- drake, Michi- gan	41.0	Wood-brown	Cottony	No separate border	None	None	None	Light cinna- mon drab to cinna- mon drab	Cottony	None	None
<i>Fomitiporia flavo-</i> <i>marginata</i> on <i>Q. nigra</i> from Walterboro, S. Carolina	19.9	Cream-color to honey- yellow to Saccardo's olive	Cottony to nodulose Concentric- ring growth	Definite Silky	None	None	None	(White mar- gin) Deep colo- rial buff	Cottony tendency toward concen- tric-ring growth	None	None
<i>P. ferrea</i> on <i>Corylus</i> sp. from Oregon	24.2	Clay color to Saval brown	Cottony Radiating to radiating ans	White Definite Fibrous	None	None	None	White (not only mar- gin) to clay color	Cottony Radiating	None	None
<i>P. ferrea</i> on <i>Alnus rubra</i> from Oregon	24.2	Clay color to Saval brown	Cottony Radiating	White Definite Fibrous	None	None	None	White (not only mar- gin) to mukado brown	Cottony Radiating	None	None

TABLE I (Concluded)
GROWTH CHARACTERISTICS OF BROWN POLYPORES ON MALT AGAR

NAME	IN LIGHT						IN DARK				
	Rate in mm. 2 weeks	Color (Ridgway)	Texture and form	Character of margin	Agar discoloration	Pore formation	Rate in mm. 2 weeks	Color (Ridgway)	Texture and form	Agar discoloration	Pore formation
<i>Fomitiporia dryophila</i> on <i>Quercus</i> sp. from Ocala National Forest, Florida	10.3	Isabella color to honey-yellow	Silky Concentric-ring growth	No border	None	None	17.7	(White margin) Napples yellow to Sudan brown	Cottony Exudations (distinct fibrous margin)	None	None
<i>Fomitiporia Earleae</i> , Strain II, on <i>L. styraciflua</i> from Kingsland, Georgia	16.6	Ivory-yellow to colonial buff to Isabella color	Cottony Concentric-ring growth	Definite Silky border	None	None	18.7	White (margin) to straw-yellow to low to avellaneous	Cottony Indefinite or definite white margin Fibrous	None	None
<i>Fomitiporia Earleae</i> , Strain I, on <i>Nyssa biflora</i> from Oseola National Forest, Florida	15.7	Ivory-yellow to colonial buff to warm buff	Cottony Concentric-ring growth	Definite Silky margin	None	None	19.9	Cream-buff (white border)	Cottony (border more fibrous than in light)	None	None
<i>T. isabellina</i> , Strain 6W, on white spruce from Selkirk, Yukon Territory	6.0	Honey-yellow to clay color	Chamois	Radiating fans, indefinite Silky or definite silky margin	None	None	6.8	White to drab gray	Silky to fibrous Radiating fans	None	None
<i>T. isabellina</i> , Strain 10W, on white spruce from Selkirk, Yukon Territory	5.9	Sayal brown to clay color	Chamois	Indefinite Silky or definite Silky	None	Present on inoculum in less than 2 weeks. On new growth in 30 days	7.3	Cartridge-buff	Silky to fibrous Concentric-ring growth Resin drops	None	Does not form pores even on inoculum in 30 days

The species which are most difficult to separate from one another on a morphological basis are contrasted in the following key:³

1. Ten-month liter flask cultures exhibiting crustlike areas which are pre-dominately hematite red..... *Fomitiporia Earleae*
(Strains I and II)
1. Ten-month liter flask cultures not exhibiting crustlike areas and hematite red not conspicuous..... 2
2. Old mycelium turning black or blackish and becoming a conspicuous part of the culture, overgrown with cottony areas of buff-colored mycelium; irregular black lines very prominent, i.e. growing all over face of culture..... *Fomitiporella floridana*
2. Old mycelium not turning blackish over large portion of culture, and such parts not overgrown with buff-colored mycelium; black lines present or absent, but, if present, not appearing extensively all over culture... 3
3. Mycelium distinctly whitish buff (not definitely brown) and exhibiting thick masses of mycelium in cultures..... *Poria pereffusa*
3. Mycelium distinctly brown, not whitish or buff, and growth not forming thick masses of mycelium in culture..... 4
4. Mycelium becoming chocolate-brown; seldom exhibiting black lines
Poria prunicola
4. Mycelium yellow-brown; black lines present..... 5
5. Nodulose or cottony..... 6
5. Not nodulose or cottony, or, if cottony, exhibiting concentric-ring growth; resin drops conspicuous..... *Fomitiporia dryophila*
6. Cottony to nodulose, mostly nodulose; fine black lines present; resin drops often present..... *Fomitiporia flavomarginata*
6. Cottony to floccose; thick, blood-red to black lines present (not abundant throughout and over cultures as in *Fomitiporella floridana*); resin drops usually not present..... *Poria punctata*

The terms used in this study are defined or explained as follows:

Arachnoid. — Cobwebby in appearance. The term is used of mycelium consisting of intertangled hyphae which are not thick or matted.

Black or brown lines. — Distinct black or brown lines which appear on the surface or at the edges of a culture.

Cerebriform. — Applied to a folded and lobed form of growth on a medium.

Concentric-ring growth. — An uneven growth of mycelium in a culture that appears in the form of circles.

Cottony. — Describes mycelium that is erect and intertwined into a thick mass of short fibrous threads that resemble cotton.

Crustlike. — Applied to a growth which becomes hardened and in the woody forms assumes the appearance of the margins of the fruiting bodies.

Darkening of the agar. — No definite brown or black lines formed in culture, but the entire medium becomes noticeably darkened because of the fungus.

Definite border. — A distinct growth of mycelium at the margin of the culture that is distinguishable from the rest of the mycelium by color or by texture.

³ In a later paper I shall revise the generic names used here.

Exudations. — Colorless or resin-like liquid drops which appear on the surface of a culture.

Floccose. — Woolly. The term is applied to long threads of mycelium, erect and intertwined into a mass of fibers that resemble wool.

Indefinite border. — No distinct growth of hyphae at the margin of a culture that can be separated from the rest of the mycelium by color or by texture.

Medium growth. — Growth, approximating 5 mm. in thickness, of the mycelium over the surface of the agar.

Nodulose. — Describes the more or less rounded masses or lumps of interwoven mycelium that characterize a culture.

Radiating. — Applied to mycelium in the form of rays, usually extending out or part way out to the margin from the point of an inoculum. Not used here to describe the type of marginal growth.

Radiating fans. — Mycelium extending out from the margin in the form of fans. The term describes the marginal growth of a culture.

Silky. — Describes the fine, parallel threads of the mycelium, ordinarily appressed or prostrate, on the surface of the agar.

Thick growth. — Growth, approximating 10–15 mm. in thickness, of the mycelium over the surface of the agar.

Thin growth. — Growth, approximating 2 mm. in thickness, of the mycelium over the surface of the agar.

Fomitiporia dryophila Murr., N. Am. Flora, 9:8. 1907.

(Plate XXXIII)

Type and important specimens:

Fomitiporia dryophila Murr. on live oak stump, Back Bay, Mississippi. Leg. Esther S. Earle, 1904. Herb. New York Botanical Garden.

Fomitiporia dryophila Murr. on *Quercus* sp., Coll. Dow V. Baxter. Ocala National Forest, Florida. Herb. Dow V. Baxter, Ann Arbor.

Fructification perennial, effused-resupinate or in patches or appearing in semiresupinate forms on dead standing trees or on logs, inseparable, up to 4 cm. thick; margin obtuse, at first "Sayal brown" becoming "drab-gray," "benzo brown," or blackish with age; context woody, "Sayal brown," somewhat glistening; tubes 2 to 10 mm. long each season and usually distinctly stratified and sometimes separate from each other upon breaking open the fruit body; mouths at first, or in early stages of development of the fructification, "honey-yellow" or "Isabella" color (and in this state thin specimens match the type of *Fomitiporia Earleae*), becoming "Sayal brown" to "snuff-brown," refracting light and often appearing lighter, 4–6 to a mm.; dissepiments thick; spores subglobose or globose, $5.5 \times 5.5 \mu$; hyphae ferruginous, 3–4 μ ; cystidia none. The color of the context will readily separate it from *F. (Poria) prunicola*. Differences in

the cultures of these two plants are also striking. The mycelium has the chocolate-brown of *F. (Poria) prunicola*, whereas that of *F. dryophila* is greenish yellow.

Allied species. — *F. dryophila* is closely allied to *Poria punctata*, but typical specimens differ from that species in habit of growth. There is a more pronounced tendency for the fructifications to become ungulate than is usual in the latter fungus. In this respect one is reminded of the habit of growth of *Fomes fulvus*. Fruit bodies of *F. dryophila* suggest immature fructifications of *F. Bakeri* (as to shape) in formation. The hymenium of *F. dryophila*, as well as the context, is distinct from that of *P. punctata* in that it is more glistening and tends to be more golden. In specimens of *F. dryophila* the mouths of the tubes are often less gray in mass than they are in *P. punctata*. Frequently there is evident in the hymenium of *F. dryophila* a convex habit of growth that has not been observed in *P. punctata*. This last feature is not to be found, however, in all specimens. But since these characters are relative they are to be considered useful only as being supplementary to the distinctions displayed by the cultures themselves. Differences exhibited by the cultures of these two species are discussed under *F. Earleae*.

Cultures. — Isolated from *Quercus* sp., Ocala National Forest, Florida. This fungus belongs to the "slow-growth" group of resupinate polypores and is also classed in both the "large-range" and the "high-temperature" categories. At first the hyphae of *F. dryophila* are mostly appressed in culture and silky. The mycelium becomes chamois-like in texture, but distinctly not floccose, as is that of *F. Earleae*, Strain I. Exudations and black-line formations appear to such an extent (in one-month-old cultures) that the fungus suggests a decided relationship to the very distinctive cultures of *F. (Poria) inermis*. Compare Plate XXXI, Figures 1–3, for growth characteristics of these fungi and *P. punctata*.

Remarks. — Striking morphological distinctions between the majority of the members of the genus *Fomitiporia* do not exist, and many of the described differences are not retained in specimens of the same plant at different stages of maturity. Since the southern species which belong to this group are particularly difficult to determine, numerous collections have been gathered

in the South and attempts have been made to collect material in all stages of development. Cultures have been prepared from these specimens, and the plants themselves have been compared with the types.

Although many of these resupinate polypores are similar macroscopically and structurally to the types, such notable and obvious differences in their appearance and in other features of growth in culture have appeared that they must be kept separate.

Rather than separate these as new species, the different cultures which were obtained from various collections and which demonstrate themselves to be distinct are termed "strains." The use of this term should not be confusing since "physiological race" or "physiological form" is commonly used to designate plants which are parasitic in their nature. (Compare *F. dryophila* in culture with *F. Earleae*, Strain I and Strain II.)

Fomitiporia Earleae Murr., N. Am. Flora, 9:9. 1907.

(Plate XXXIV, Fig. 1: Plate XXXVI)

Type and important specimens:

Fomitiporia Earleae on oak, Biloxi, Mississippi. Esther S. Earle, 1904. Herb. New York Botanical Garden.

Fomitiporia Earleae on *Nyssa biflora*, Strain I. Ocala National Forest, Florida. Herb. Dow V. Baxter, Ann Arbor.

Fomitiporia Earleae on *Liquidambar styraciflua*, Strain II. Kingsland, Georgia. Herb. Dow V. Baxter, Ann Arbor.

Fructification woody, in subcircular or elongate patches up to 1.5 cm. long, and on the bark of logs for a distance of 1 meter or more, or appearing as somewhat ungulate and in this form suggesting that of *F. dryophila*; but in such specimens the hymenium appearing in more or less subcircular or irregular patches over the old growth; margin thin, adnate, sterile at first, "Sayal brown," but the border of the fructification turning (old tube layers) red, or blackish red, "army brown" or "seal-brown," to black, becoming resinous or waxy in appearance; tubes 2-5 mm. long each season; mouths 5-6 to a mm., "tawny olive," refracting the light; dissepiments thick; spores globose, smooth, hyaline, $5 \times 5 \mu$; mature hyphae thick-walled, mostly $2-3 \mu$ in diameter, hyphae stuffing the tubes hyaline to ferruginous, much branched; cystidia none but sometimes hyphal pegs are present.

Allied species. — *F. Earleae* is so closely related to both *F. dryophila* that it is essential to have material which illustrates the character of the marginal or border portions of the fructification of mature specimens if one is to separate the two plants without matching or comparing cultures of the unknown with those of known identity. In *F. Earleae* the border portions of the fruit body (not exhibited in one of the specimens of the type collection, but to be observed in another plant of the same collection) become waxy or somewhat resinous, as is to be observed in the margin of typical specimens of *Fomes pinicola* on hemlock. In *F. dryophila* the border growth or surface of the more ungulate forms is dull, as in fruit bodies of *Fomes Bakeri*, or if resinous toward the margin, they present the same dull appearance at the back, nearest the substratum.

The type of border growth of mature plants is exceedingly important, and its significance is increased, since in both Strain I and Strain II here described there is a tendency for a dark red (haematite red), crustlike formation to appear in old cultures of these two fungi. This crust becomes dull red or blackish red in old cultures (8 to 10 months) and is suggestive of the dark black-red border to be found in mature fruit bodies in nature. This crustlike formation occurs without the appearance of exudations on the surface of the culture. Cultures of *F. dryophila*, on the other hand, show an abundance of exudations that appear to be very resinous. These may dry to form a waxy crust in 8- to 10-month-old liter flask cultures, so that they give to the marginal growth of one of the specimens the identical appearance to be observed in the type collection.

The cultures of *F. Earleae*, Strain I and Strain II, are different from those of *F. dryophila* chiefly in their more cottony appearance (chamois-like texture in *F. dryophila*) and their tendency to become crustlike without the formation of exudations (Pl. XXXII, Figs. 1-2). The cultures of Strain I and Strain II of *F. Earleae* are different also in color shades from those of *F. dryophila* (Table I).

Cultures and fruit bodies alike of *F. Earleae*, Strain II, actually seem to point to an intermediate form between *F. Earleae*, Strain I, and *F. dryophila*. The cultures of the two latter fungi are so different from each other that they can be distinguished

without critical study. Though the features of Strain II are different from either, certain characteristics of both Strain I and *F. dryophila* are present that suggest an intermediate form (Table I).

The fruit bodies of all three plants have been compared with the type collections, and these, too, suggest that the collection from Georgia (at first referred to *F. Earleae* with some hesitancy) is an intermediate form. Rather than describe this as a separate species, it was believed to be preferable to establish it as a strain of *F. Earleae*, based upon the evidence secured from cultures. It is possible to interpret it as either species if morphology alone is used in the diagnoses.

Attention is also called to the fact that it would, of course, be possible to redescribe *F. Earleae* as another strain of *F. dryophila* and to regard *F. Earleae* as only a "growth form" of *F. dryophila*. The plants, however, are retained as separate species for the following reasons: the tendency of *F. dryophila* to form ungulate fruit bodies; the tendency of the fruit body to separate in different tube layers (this latter feature is not to be observed even in old, thick specimens of *F. Earleae*); and, particularly, the dull gray appearance of the border growth of *F. dryophila* instead of the more resinous type of *F. Earleae*. These considerations alone, however, are not sufficient to keep the plants apart, but it is believed that the marked differences observed in cultures are so striking that there is reason enough to retain the species name. It is to be emphasized that the noticeable diversity in the cultures of these two fungi is much greater than in many of those from the fruiting bodies of the more commonly recognized polypores, and this information is used to support the "relative" characters already mentioned.

The cultures of *P. punctata* from *Rhus vernix* should also be compared with those of *F. Earleae*, Strains I and II, since the fruiting bodies of these fungi (particularly those which correspond to the collections on *Liquidambar styraciflua* may be confused. Color distinctions may be readily used to separate the fungi in culture. Cultures of *P. punctata* are usually lighter in color than is either strain of *F. Earleae*. The appearance of "haematite red" in old cultures (8 to 10 months) of *F. Earleae*, Strain I, and the "yellow ocher" in 8- to 10-month-old cultures

(similar to the color of the context of *Pol. gilvus*) of *F. Earleae*, Strain II, will readily separate these fungi from *P. punctata*. *P. punctata* exhibits a more uniform color, "cream-buff" to "chamois"; there are no reds and browns, dark and light yellow browns, or dark and light browns in the same culture.

Cultures. — Strain I, isolated from *Nyssa biflora*, Ocala National Forest, Florida. It belongs to the "slow-growth" class and also to that group termed "large-range." It grows best in the dark. The cultures are characterized by an abundant growth of mycelium that soon assumes a flocculent nature and becomes "haematite red" and somewhat crustlike in areas showing this color. There is no greenish brown zone appearing at the border of the culture, as in Strain II. No exudations appear. Care should be taken, however, that these minor differences be not allowed to confuse the species. When Strain I from *Nyssa* and Strain II from *Liquidambar* are cultured on red-gum or basswood blocks, the two isolates cannot be distinguished from each other.

F. Earleae, Strain II, isolated from *Liquidambar styraciflua*, Kingsland, Georgia. This strain is similarly characterized by the fact that it belongs to the "slow-growth" class and also to that group termed "large-range." It, too, grows best in the dark. The chief features are (1) the distinctive olive-green color that appears in one-month-old cultures and in 8- to 10-month-old cultures, and (2) the "yellow ocher" of the mycelium and the similarity in color to that of the context color of *Pol. gilvus*. Additional features of this strain are described in Table I and also under the heading, "Allied species."

Habitat. — *Liquidambar styraciflua*, *Nyssa biflora*, *Quercus* sp.

Distribution. — Florida, Mississippi, Texas.

Fomitiporia flavomarginata Murr., N. Am. Flora, 9: 11. 1907.

(Plate XXXV)

Type and important specimen:

Fomitiporia flavomarginata Murr. on hardwood logs, F. S. Earle and W. A. Murrill, 599. 1905. Alto Cedro, Cuba. Herb. New York Botanical Garden.

Fomitiporia flavomarginata Murr. on *Quercus nigra*, Walterboro, South Carolina, Coll. Dow V. Baxter, 1935. Herb. Dow V. Baxter, Ann Arbor.

Fructification perennial, brown, entirely resupinate, effused in round or subelliptical patches 5 × 5–7 cm. or more, mostly 2 to 3 mm.

thick; margin thin, adnate, irregular, mostly less than 1 mm. wide, "clay color," at length black, sometimes separating from the substratum; context thin; tubes distinctly stratified, mostly 2-4 mm. long but up to 10 mm. when in an oblique position; mouths "Sayal brown," "snuff-brown" to "bister," 7-8 to a mm., refracting light, entire, thick-walled; dissepiments entire; basidia hyaline, 4-spored, $3-4 \times 11-18 \mu$; spores at maturity very pale ferruginous but immature spores mostly hyaline, subglobose, $4 \times 3-4 \mu$; hyphae mostly 2μ in diameter, brown except when first formed, seldom septate; cystidia none or if present appearing as more or less diamond-shaped structures which do not extend beyond the basidia, $4-7 \times 9-11 \mu$.

Allied species. — The brown resupinate polypores are exceedingly difficult to distinguish, even if spore material is abundant, since it is often perplexing to determine whether the spores are hyaline, pale ferruginous, or brown. In this study *Fomitiporella Langloisiana* is set up as an example of a plant having definitely brown spores. When difficulty is found in deciding whether the spores are pale ferruginous or hyaline, it is necessary to match cultures obtained from known sources with those of the unknown specimen.

Macroscopically, this plant might be readily confused with old specimens of *Poria ferrea*, which can be separated easily from this species by spore sizes and by cultures. If the spores of this plant are considered pale ferruginous — as some seem to be, but not always — comparisons should be made with *F. Langloisiana*. The spores of *F. Langloisiana* are distinctly a chocolate brown, however, and this feature of definitely brown spores should be held for this species. This character, if followed, should avoid confusion between the two plants. Both *F. Langloisiana* and *Fomitiporia flavomarginata* refract the light.

Fomitiporia Maxoni might suggest *F. flavomarginata*, the context of which is somewhat more yellowish and suggests the color of *Polyporus gilvus*.

Cultures. — Isolated from *Quercus nigra*, Walterboro, South Carolina. *F. flavomarginata* belongs to the "slow-growth" class. The temperature range is large, and the plant grows best in the dark. One-month-old cultures of this fungus are readily distinguished from closely allied forms by being predominately yellow, that is,

"straw-yellow." In culture the fungus shown most nearly resembles that of *F. Earleae*. In texture it is similar to several of the resupinates, but generally it exhibits a thinner growth on the surface of the agar than its allies do.

Habitat. — *Quercus nigra*.

Distribution. — Louisiana, South Carolina.

Fomitiporella Langloisiana Murr., N. Am. Flora, 9:13. 1907.

(Plate XXXIV, Fig. 2)

Type specimen:

Fomitiporella Langloisiana Murr. near St. Martinsville, Louisiana. A. B. Langlois, 2430. 1895. Herb. New York Botanical Garden.

Fructification perennial, inseparable, up to 5 mm. thick; margin thin, adnate, irregular, mostly less than 1 mm. wide, "cinnamon-buff" to "clay color"; context thin, less than 0.5 mm., stratose; tubes mostly 2–3 mm. long each season; mouths "snuff-brown," "bister," refracting the light, circular, 6 to a mm., dissepiments entire; spores subglobose, smooth, brown, $3\text{--}3.5 \times 4 \mu$; hyphae brown; cystidia none.

Allied species. — *Fomitiporella Langloisiana* may be mistaken macroscopically with a number of species in the *Fomitiporia* group as well as with forms in its own genus. Of these plants *Fomitiporia flavomarginata* is perhaps one of the most confusing, since its spores are often pale ferruginous at maturity, or at least one might interpret them as such. The definitely brown spores of *F. Langloisiana* will separate these two polypores. Since other plants listed under the genus *Fomitiporella* are described as having "pale ferruginous" spores, the danger of misinterpreting hyaline forms (*Fomitiporiae*) for those that are "pale ferruginous" (*Fomitiporellae*) is so great as to prevent this feature, alone and without other characters, from being a practical means of differentiation. For this reason *F. Langloisiana* is established here as an example of a species possessing definitely brown spores. Comparisons of this plant with other species of the genus will be made later.⁴ *F. Langloisiana*, however, is easy to distinguish

⁴ All the allies of *F. Langloisiana* which have been described as having pale ferruginous or ferruginous spores have not been studied critically microscopically and in culture, but it is hoped to continue the revision of this genus as fresh material which matches the type is found for culture work.

from *Fomitiporia* ((*Fomitiporella*) *Poria*) *betulina* on the basis of spore color. The spores of this latter plant are regarded as hyaline and are not colored in the sense that they are in *F. Langloisiana*. *Fomitiporella* (*Poria*) *inermis*, which is found almost exclusively on *Ilex*, is easily distinguished macroscopically and microscopically from *F. Langloisiana*. The following features will separate *F. inermis* from *F. Langloisiana*: the glistening tubes; the arrangement, which is usually oblique; the checking of the fruit body and its splitting naturally into many cracks; and the relatively large size of the mouths.

Poria crustulina Bres., *Mycologia*, 17:75. 1925.

Type, cotype, and important specimens:

Poria crustulina Bres., sp. nov., type on *Picea Engelmannii*. Leg. J. R. Weir, 15025. Division Pathological and Mycological Collections, Washington.

Poria crustulina Bres. on *Picea Engelmannii*, Coolin, Kaniksu National Forest, Idaho. Leg. J. R. Weir, Division Pathological and Mycological Collections, Washington.

Poria crustulina Bres. on *Picea Engelmannii*, Agassiz, British Columbia. Leg. J. R. Weir, 8162. Division Pathological and Mycological Collections, Washington.

Poria crustulina Bres., sp. nov., on *Picea sitchensis*, Bellingham, Washington. Leg. J. R. Weir. Division Pathological and Mycological Collections, Washington.

Fructification mostly annual, sometimes perennial, separable when fresh on the more even surfaces, drying to 2 mm., thick-effused to a distance of 30 cm. or more in irregular patches, usually on bark of fallen timbers; margin tomentose to arachnoid, whitish to "pale pinkish buff," sterile at first, often becoming fertile in age, up to 4 mm. wide, thin; subiculum up to 2 mm. thick, concolorous with the margin; tubes often becoming somewhat resinous, up to 5 mm. but mostly about 33 mm. long each season; mouths circular to angular, 1-3 to a mm., "pale pinkish buff" drying to "pinkish buff," "cinnamon-buff" to "clay color"; dissepiments often fimbriate; basidia 2-4-spored, $11-16.5 \times 5.5-7 \mu$; spores hyaline, smooth, cylindric to allantoid, $5.5-7(8) \times 2-3 \mu$, usually abundant in most mounts; hyphae smooth or encrusted, thick-walled, septate, mostly $3-4 \mu$ in diameter.

Allied species. — That this plant has the general aspect of a short-tubed or perhaps an undeveloped *P. subacida* probably accounts, in part, for the fact that the species is not to be found under this

name in many herbaria. It has probably been mistaken in the field for that species, since in habit of growth, color, and even in size of the mouths the two plants are remarkably similar. In Europe it would probably be mistaken for a thick form of *P. aneirina*. The cylindric or allantoid spores of the plant described here will readily separate it from both *P. subacida* and *P. aneirina*. The relatively thick form of this plant will aid also in separating it from the typical *P. aneirina*.

Some collections of this plant have been tentatively called *P. flavicans* in America, but the real *P. flavicans* is totally different. *P. crustulina* differs in spore measurements from that plant and does not possess at all the soft-yellowish characteristics of *P. flavicans*. The general aspects of *P. flavicans* suggest a yellow *Pol. sericeo-mollis*.

In young stages of development *P. crustulina* resembles the macroscopic appearance of *P. attenuata* var. *subincarnata*. The width of the spores will readily separate the two plants. Those of *P. attenuata* var. *subincarnata* are only 1 μ wide, whereas the spores of *P. crustulina* are 2–3 μ in width.

Cultures. — Isolated from *Picea glauca*, Tanana, Alaska. Cultures produce a thick mat much more fluffy than those exhibited by *Poria subacida*.

Habitat. — *Abies lasiocarpa*, *P. Engelmannii*, *P. glauca*, *P. sitchensis*, *Pinus contorta*, *Tsuga heterophylla*.

Distribution. — British Columbia, Nova Scotia, Ontario, Yukon Territory, Alaska, Colorado, Idaho, Michigan, New York, South Dakota, Utah, Washington.

Occurrence. — This species is very probably much more common on coniferous woods throughout the northern forest regions of North America than the known distribution records indicate. It is common on fallen logs in the interior forests of Alaska, northern British Columbia, and the Yukon Territory, but it does not occur frequently in the "rain-forest belt." I have observed it at many localities in both the Toklat River and the Savage River districts in the Mt. McKinley region. A collection from the Kenai Peninsula in Alaska represents the only known record of its occurrence in the coastal forest. The fungus is found at the higher altitudes in the Rocky Mountains, and it is known from Isle Royale, Michigan, and from Nova Scotia.

Trametes isabellina Fr., Hymen. Eur., p. 585. 1874.

(Plate XXXVII, Fig. 2)

Fomes tenuis Karst., Medd. Soc. Fauna. Fl. Fenn., 14: 81. 1887.*Polyporus tenuis* (Karst.) Romell, Arkiv f. Bot., 11: 24. 1911.*Trametes setosus* Weir, Journ. Agric. Res., 2: 164. 1914.*Phellinus isabellinus* (Fr.) Bourd. Galz., Hymen. Fr., 1: 622. 1927.*Trametes tenuis* (Karst.) in American literature. Not *Polystictus tenuis* Link.

Types and important specimens:

Trametes isabellina Fr. orig. ex. Blytt. Herb. of Bres., Stockholm.*Trametes tenuis* Karst. on pine Mustiala, Finland. Leg. P. A. Karsten, 1878.

Ex Herb. Karsten, Herb. Mycology. Lars Romell, Stockholm.

Fructification perennial, coriaceous to woody, sessile, effused-reflexed, or entirely resupinate, confluent; pileus up to $10 \times 1.5 \times 0.6$ cm., surface hirsute to glabrous, zonate, "mouse-gray," "benzo brown," "Chaetura drab" to blackish, margin tomentose, velvety, sterile at first, "clay color," "ochraceous tawny," "tawny olive," becoming fertile in age; resupinate specimens first in circular or irregular patches, becoming confluent and effused; margin "clay color," "ochraceous tawny," "Sudan brown," "tawny olive," sterile, 1-2 mm. wide; context "cinnamon-brown," less than 0.5 and mostly less than 0.3 mm. thick; tubes 1-4 mm. long, "Sudan brown" to "Brussels brown"; mouths round to angular, 2-6 mostly 3-4 to a mm., concolorous with the tubes; dissepiments thick, entire; basidia $8-13 \times 3-4 \mu$; spores hyaline, smooth, cylindric, $5.5-7 (9) \times 1.5-2 \mu$; setae abundant, long, pointed, both subulate and ventricose, $26-44 \times 3-7 \mu$; hyphae brown, straight, unbranched, aseptate, $2-3 \mu$ in diameter.

Allied species. — *Poria viticola*, *P. contigua*, *P. superficialis*, *P. floccosa* Fr. *sensu* Romell, are now considered to be large-pored variations (pores mostly 2-3 to a mm.). *P. racodioides* Pers. is also considered to be a large-pored form with a wide sterile border. The so-called typical forms of these plants are supposed to exhibit larger pores than those described for *T. isabellina*.

P. ferruginosa differs from the resupinate forms of *T. isabellina* in spore size. The spores of *P. ferruginosa* are globose-ellipsoidal, $4-5 (4) \times (3) 2.5-4 \mu$, whereas those of *T. isabellina* are $5.5-7 \times 1.5-2 \mu$. The long projecting setae of *T. isabellina* are also helpful in separating not only these two, but *T. isabellina* and

P. ferrea as well. The spores of the latter two fungi are cylindric. *T. isabellina* is found abundantly on conifers; *P. ferrea* is usually on hardwoods.

No difficulty has been experienced in distinguishing the fruit bodies of *T. isabellina* from *T. odorata* (*T. protracta*). The abundant setae which are found in the former will readily separate the one from the other. Furthermore, the rots produced by these two fungi are different. *T. isabellina* causes a small white pocket rot. These pockets, which are confined to the ring, coalesce in the final stages of the decay process and a ring-scale rot is produced. *T. odorata*, on the other hand, causes a brown rot.

Cultures. — Strain 6W, isolated from *Picea glauca*, Selkirk, Yukon Territory, and Strain 10W, isolated from *P. glauca*, Selkirk, Yukon Territory. Both strains are identical with reference to their growth rate, color, and texture. They are most closely allied in culture to *Poria ferrea* and *P. ferruginosa* in color and texture, but there is obviously a difference in the growth rate of both strains of *T. isabellina*, in contrast to all the cultures obtained from *P. ferrea* and *P. ferruginosa* on a great variety of substrata and range (Table I). *T. isabellina* grows much more slowly in culture than *P. ferrea* or *P. ferruginosa*.

The two strains of *T. isabellina* differ in that one appears to be homothallic, while the other one is possibly heterothallic. At any rate, tube formation and the production of spores commonly take place in less than two weeks in Strain 10W, but no spore or tube formation has developed in cultures of Strain 6W.

Habitat. — *Abies grandis*, *A. lasiocarpa*, *Chamaecyparis lawsoniana*, *Larix occidentalis*, *Libocedrus decurrens*, *Picea Engelmannii*, *P. glauca*, *P. mariana*, *Pinus attenuata*, *P. banksiana*, *P. contorta*, *P. monticola*, *P. ponderosa*, *P. strobus*, *P. taeda*, *P. virginiana*, *Populus tremuloides*, *Pseudotsuga taxifolia*, *Quercus alba*, *Sequoia sempervirens*, *Thuja occidentalis*, *T. plicata*, *Tsuga heterophylla*.

Distribution. — Alberta, British Columbia, Yukon Territory, Alabama, Alaska, California, Colorado, Idaho, Maryland, Massachusetts, Michigan, Minnesota, Montana, New Jersey, Oregon, South Dakota, Virginia, Washington, West Virginia, Wisconsin, Wyoming.

Remarks. — In Sweden this fungus is a very common one on old

fence rails. Swedish plants are mostly "snuff-brown" to "Brussels brown" when freshly collected.

The fungus is one of the most abundant of the polypores found in certain sections of the western mountains of North America, where it causes a sap and heartwood rot of fallen trees. It is particularly abundant on lodgepole pine. Hubert (4) reports it as a common rot of stored coniferous logs also.

Poria rancida Bres., F. Trid., II: 96. 1892.

(Plate XXXVII, Fig. 1)

Type and important specimen:

Poria rancida Bres., sp. nov., Herb. of Bresadola, Stockholm.

Poria rancida Bres. Kingston, Ontario, Canada. Coll. H. T. McClement; det. Dow V. Baxter. C. G. Lloyd Mycological Collection, 16385.

Fructification somewhat corky, becoming hard, ossified, and the surface becoming somewhat granular or plaster-like, ramifying over and matting coniferous needles and bark on or near the ground, up to 2-10 mm. thick and varying with the irregularities of the soil or surface of the substrata, whitish at first, becoming "pale mouse-gray" to "pinkish buff"; margin becoming fertile; subiculum up to 8 mm., but varying according to the depth to which the fungus penetrates in the forest floor; tubes 2 to 4 mm. long (Bres.; [probably in fresh plants]), 0.5 to 1.0 mm. and mostly less than 1 mm. in length in dried specimens, becoming ossified; mouths variable, round or subangular, 2-3 to a mm.; "pale mouse-gray," "light mouse-gray" to "pinkish buff" and "cinnamon-buff"; dissepiments thick; basidia 4-spored, $13-18 \times 4-7 \mu$; spores hyaline, cylindrical $(4.5)5.5-7 \times (2)2.5-3 \mu$; hyphae $1-4 \mu$, collapsible, thick-walled, abundant clamp connections.

Allied species. — According to collections in the Bresadola herbarium at Stockholm, *P. rancida* most nearly resembles *P. chrysoloma* Fr. as interpreted by Bresadola. The spores given for *P. chrysoloma* Fr. *sensu* Bresadola are $5-6 \times 4-4.5 \mu$; those of *P. rancida* Bres., $(4.5)5.5-7 \times (2)2.5-3 \mu$. Specimens of both these plants are very similar macroscopically and, in general, are found in similar habitats (very unusual habitats for the majority of the species of the resupinate polypores), and both plants become somewhat ossified upon drying. Although in *P. chrysoloma* faint

tints of pink or cinnamon prevail instead of the white or gray common in *P. rancida*, these colors, too, are to be detected in dried plants of the latter species. Young specimens of *P. ambigua* might be mistaken for *P. rancida* and particularly so when they are growing on the ground about tree roots. Dried collections of the former are somewhat friable, whereas those of *P. rancida* are ossified.

Remarks. — In speaking of *Trametes abietis* Karst., Romell (6) states: "It is not mentioned in Fries' works, unless *P. chrysoloma* is the resupinate form of it." He adds that this seems probable, although it cannot be demonstrated now, since authentic specimens are not known to exist. This authority also calls attention to the fact that the *P. chrysoloma* Fr. as interpreted by Bresadola "is close to his [Bresadola's] *Poria rancida*."

Occurrence. — Rare.

Habitat. — On hemlock bark and needles on ground. On Larix needles in the type.

Distribution. — Ontario, California.

UNIVERSITY OF MICHIGAN

LITERATURE CITED

1. Baxter, Dow V. 1934. Some Resupinate Polypores from the Region of the Great Lakes. V. Pap. Mich. Acad. Sci., Arts and Letters, 19 (1933): 305-332.
2. ——— 1935. Some Resupinate Polypores from the Region of the Great Lakes. VI. *Ibid.*, 20 (1934): 273-281.
3. ——— 1936. Some Resupinate Polypores from the Region of the Great Lakes. VII. *Ibid.*, 21 (1935): 243-267.
4. Hubert, E. E. 1931. An Outline of Forest Pathology, pp. 1-543. John Wiley and Sons, New York.
5. Murrill, W. A. 1907. Polyporaceae. N. Am. Flora, 9: 1-72.
6. Romell, Lars. 1911. Hymenomycetes of Lapland. Arkiv f. Bot., 11: 1-35.

PLATES XXXI-XXXVII

PLATE XXXI

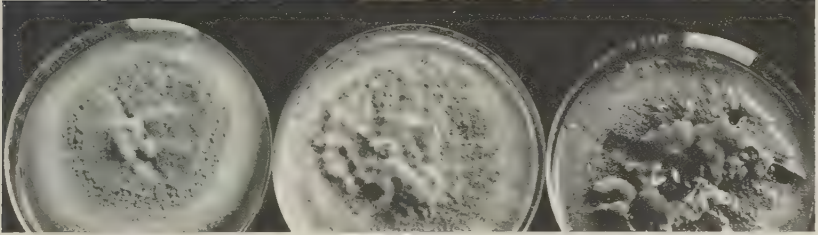


FIG. 1. *Poria inermis* from *Ilex verticellata*, Whitmore Lake, Michigan

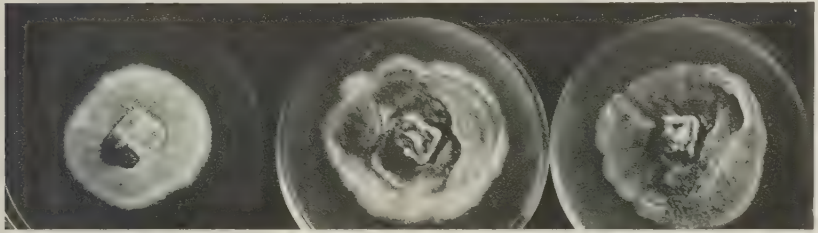


FIG. 2. *Fomitiporia dryophila* from *Quercus* sp., Ocala National Forest, Florida

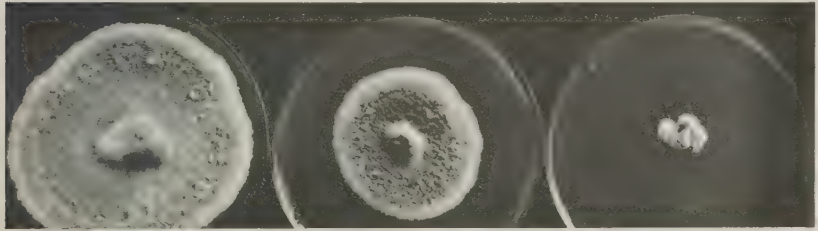


FIG. 3. *Poria punctata* from *Rhus vernix*, Michigan

Resupinate polypores cultured on malt agar at 25°, 30°, and 35° C. (cultures two weeks old)

PLATE XXXII

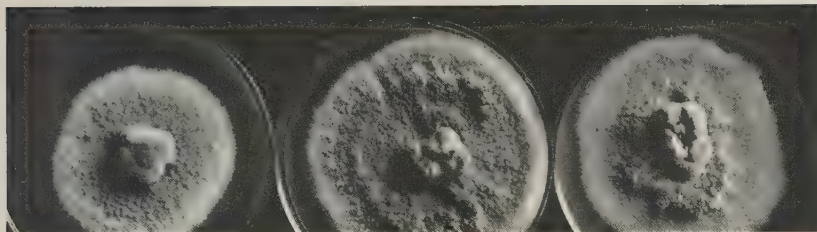


FIG. 1. *Fomitiporia Earleae*, Strain I, from *Nyssa biflora*,
Osceola National Forest, Florida

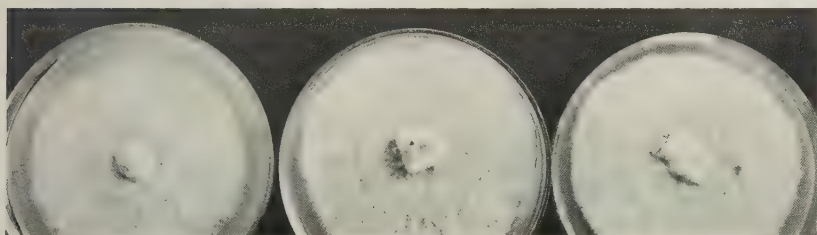


FIG. 2. *Fomitiporia Earleae*, Strain II, from *Liquidambar styraciflua*,
Kingsland, Georgia

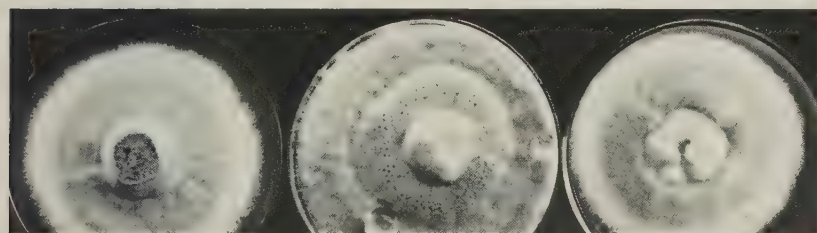


FIG. 3. *Pol. glomeratus?* from *Quercus laurifolia*, Ocala National Forest, Florida
Resupinate polypores cultured on malt agar at 25°, 30°, and 35° C. (cultures two
weeks old)

PLATE XXXIII

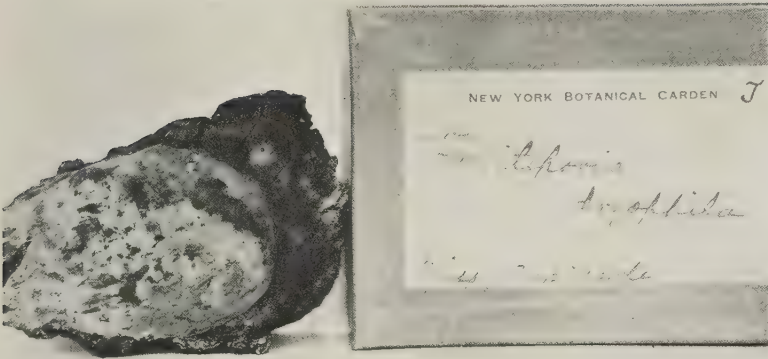


FIG. 1. *Fomitiporia dryophila* Murr. Type Specimen



FIG. 2. *Fomitiporia dryophila* Murr. on *Quercus* sp., from Ocala National Forest, Florida. Upper figure exhibits young growth of *F. dryophila* that suggests *F. Earleae*

PLATE XXXIV

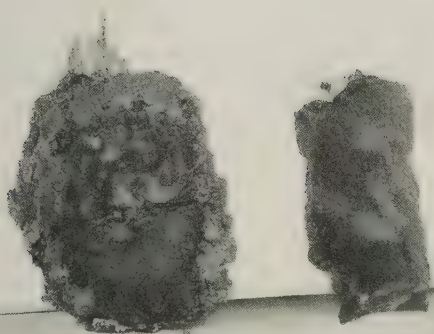


FIG. 1. *Fomitoporia Earleae* Murr. Type specimen

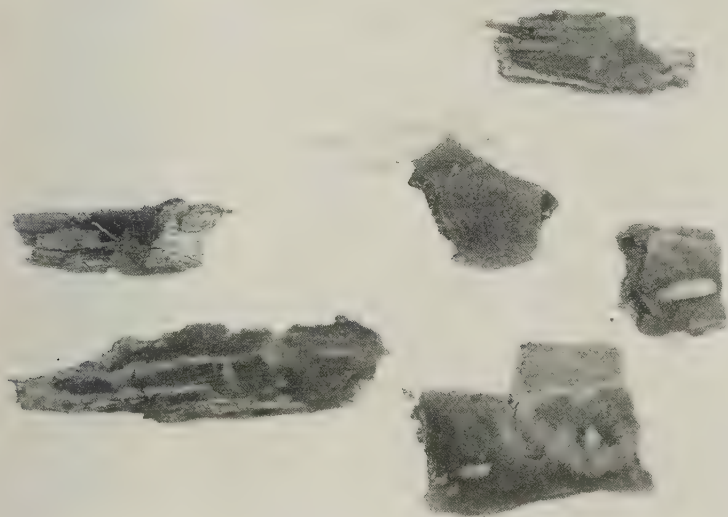


FIG. 2. *Fomitiporella Langloisiana* Murr. Type specimen

PLATE XXXV

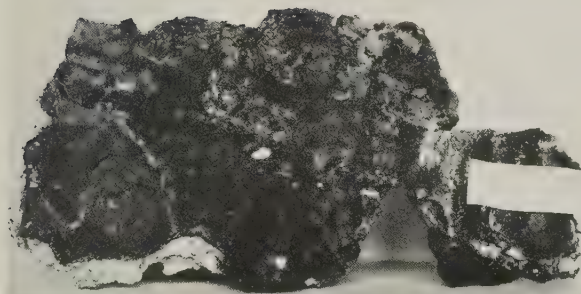


FIG. 1. *Fomitiporia flavomarginata* Murr. Type specimen

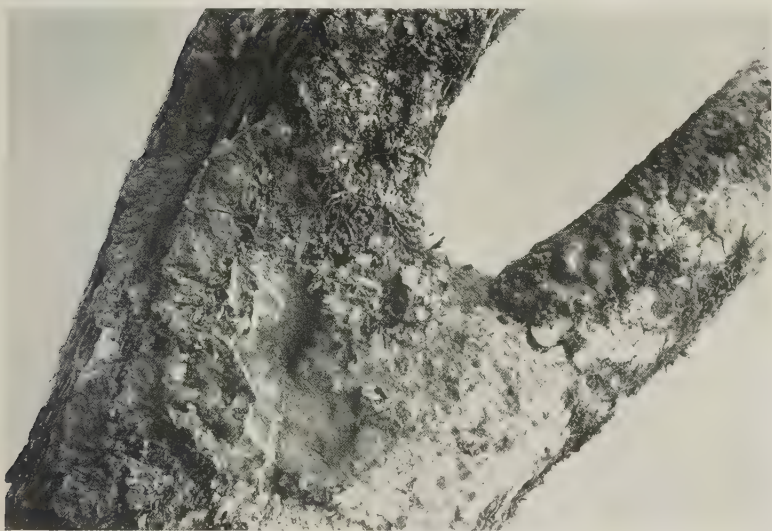


FIG. 2. *Fomitiporia flavomarginata* Murr.
from Walterboro, South Carolina

PLATE XXXVI



FIG. 1. *Fomitiporia Earleae* Murr., Strain I, on *Nyssa biflora*, Osceola National Forest, Florida



FIG. 2. *Fomitiporia Earleae* Murr., Strain II, on *Liquidambar styraciflua*, Kingsland, Georgia

PLATE XXXVII



FIG. 1. *Poria rancida* Bres. Specimen in the Bresadola Herbarium,
Naturhistoriska Riksmuséet, Stockholm, Sweden



FIG. 2. *Trametes isabellina* on fence rails, Upsala, Sweden

TESTS USED IN COMPARING BACK PUMPS

RONALD L. BIRD

INTRODUCTION

THE testing and rating of back pumps was started at the Michigan Forest Fire Experiment Station in 1932. All types of available pumps were used in these tests: single-action and double-action trombone, plunger, and compressed-air.

TESTS AND RESULTS

To eliminate as far as possible variations in the personal element, all test work was done by one operator. The catchment tests for accuracy were conducted out of doors on calm or nearly calm days, since a light wind would deflect the stream. Each test, at a given distance, was carried over several days to permit compensation for differences due to the personal equation and wind currents.

Since accuracy was an important consideration, it was necessary to build a target or catchment tank. A galvanized tub with a top diameter of two feet was used for this purpose. A large hole was cut in the bottom, and a five-gallon gasoline can, with the bottom removed, was bolted underneath in an inverted position. This unit was mounted on a three-legged stand. A gauge made of a small board with a groove cut down the middle, into which a glass tube was fitted, was placed on one leg of the stand. The glass tube was connected to the tank by a rubber hose fastened to the pouring spout of the gasoline can. The tank was leveled for purposes of graduation, and water poured into it until it appeared in the glass tube. At this position a mark, which was called the "zero point," was made. The gauge was then calibrated by pouring water into the tub, one pound at a time. The spaces between the one-pound marks were subdivided into five equal parts. Since it was possible to interpolate between these smaller intervals, the amount of water in the catchment tank could be read to approximately 0.012 of a gallon.

Five small triangular platforms were built on which to set the catchment tank. These were erected at distances of ten feet from center to center, each at the same level. An operator's stand was then constructed so that its nearest edge was ten feet from the center of the first small platform and as high as the top of the catchment tank when placed on any one of them. Thus the operator was standing in the same relative position as a man directing a stream of water at a fire on the ground.

Each pump was weighed both empty and full; the type of nozzle and the size of orifice were recorded, as well as the width, thickness, and height of the tank. To eliminate any variation in the amount of water in the tank, it was always filled to overflowing for weighing and test work.

Five tanks of water were discharged at the target at each distance. Pumping was stopped when the pump started to shoot air and its maximum efficiency was lost. The results of the tests at each distance were averaged, the mean being accepted as the amount that could be delivered in a two-foot circle at that distance. These results were later interpreted in terms of both gallons and percentage of the actual water discharged. The pumping operation was not continuous, but was broken up into several periods to allow a short rest whenever the operator's arm started to tire.

The amount of water actually discharged during the test was the difference between the full and the exhausted weights of the pump. The latter was the average weight at the end of the test, one measurement being taken at each distance.

The following additional data were recorded for each pump: the number of strokes and the amount of time necessary to discharge the water from the tank; the number of strokes per minute; the volume discharged per minute; the volume discharged per stroke; the maximum nozzle pressure; and the percentage of mechanical efficiency. The data for the pump types are presented in the accompanying tables. Also, notes on desirable and undesirable qualities were made by the operator and were used in making suggestions to the manufacturers for improving their products.

The number of strokes required for discharge was found by counting the strokes on one tank at each distance and averaging the results. The total time for discharge, which was secured by timing each pumping period with a stop watch, was taken on one

test at each distance, with the mean used as the final figure. From these data, volume per minute, strokes per minute, and volume per stroke can easily be computed.

The maximum nozzle pressure was obtained by connecting a pressure gauge into the discharge line just back of the nozzle and operating the pump as rapidly as possible.

The percentage of mechanical efficiency of pumps of the trombone and the plunger types was calculated by dividing the actual by the computed displacement. The water delivered by five complete strokes was caught in a pail and measured to the nearest cubic centimeter, with the average used as the actual discharge. By measuring the diameter of the pump cylinder and the length of the piston stroke the displacement could be computed to the nearest cubic centimeter. No efficiency tests were conducted with the compressed-air type.

TABLE I

QUANTITIES OF WATER DELIVERED IN A CIRCLE TWO FEET IN DIAMETER
BY PUMP TYPES AT RANGES FROM TEN TO FIFTY FEET

Type of pump	Distance in feet				
	10	20	30	40	50
	Percentage of actual discharge				
Compressed-air	98.5	72.8	31.7	8.5	0.0
Single-action trombone ..	89.8	51.6	12.3	2.7	0.0
Double-action trombone .	83.5	41.0	11.6	1.0	0.0
Plunger	80.7	24.8	9.1	3.2	0.0

TABLE II

RESULTS OF COMPARATIVE TESTS OF PUMP PERFORMANCE
BY TYPES

Type of pump	Pressure, pounds per square inch	Volume, gallons per minute	Strokes per minute	Percentage of mechanical efficiency
Compressed-air	42	0.42	72.0	...
Single-action trombone ...	47	0.78	32.9	40.5
Double-action trombone..	48	0.96	43.9	46.4
Plunger	63	1.73	53.0	41.8

CONCLUSIONS

The work to date has brought out the necessity of securing other data before the present data can be analyzed to best advantage. We must know the maximum horizontal and vertical ranges, the maximum accuracy, and the maximum striking force for any size of nozzle at any given pressure. Plans are now under way to obtain this information. To insure accurately controlled pressures a geared rotary power pump will be used in this work.

DEPARTMENT OF CONSERVATION
FOREST FIRE EXPERIMENT STATION
ROSCOMMON, MICHIGAN

RELEASE CUTTINGS IN PLANTATIONS OF WHITE AND NORWAY PINE

LEIGH J. YOUNG

University of Michigan

and

FRANCIS H. EYRE

Lake States Forest Experiment Station

St. Paul, Minnesota

INTRODUCTION

WITH the advent of the Emergency Conservation Work and the establishment of the CCC camps, forest culture has become something more than mere theory. Cultural work in young stands and care of plantations have been activities of high priority in the camps, and much time and effort have gone into such forest practices as thinning, pruning, weeding, cleaning, and release cuttings.

Unfortunately, in the Lake States region very little information, of either a practical or an experimental nature, on how to treat young stands was in existence when this large emergency program got under way. None the less, it was necessary to push the work and to emend incorrect practices as new information became available. Results of past experiments in the care of young stands or plantations are thus especially valuable at this time to help guide the practice of intensive forestry that is going on in the CCC camps. In this paper the results of release cuttings in three separate pine plantations, two in Michigan and one in Minnesota, are presented.

Because of the presence in the Lake States of millions of acres upon which the original forest has been denuded or replaced by stands of inferior species and quality, the problem of restoring more valuable species on these areas is of great importance. One method of obtaining this result is underplanting the inferior stands with better species, which are to be released later by cutting all, or portions, of the overstory. On some of the state forests in Michigan, and in other places as well, the first step in this process has

been taken. In many cases the underplanted species, especially in Michigan, has been white pine, because on many sandy soils a better catch is secured under cover than in the open, and the pines protected by an overhead canopy are less susceptible to damage from frost and weevils.

In 1928 a study was initiated by the School of Forestry and Conservation of the University of Michigan in coöperation with the Lake States Forest Experiment Station for the purpose of determining whether underplanted white pine will react sufficiently to release from the influence of an overhead cover to justify the cutting of such a cover in various ways.

LOCATION AND DESCRIPTION OF PLOTS

Higgins Lake Plots

The area selected as the location for the first series of plots is on the Higgins Lake State Forest in Crawford County, Michigan, covering a strip of practically level land. The overhead cover on this strip was composed of white and red oaks, red maple, large-toothed and trembling aspens, and white and Norway pines. The age of the cover was between 40 and 45 years, except for two large white oaks and one Norway pine that were left from the original forest. The area was underplanted with white pine in 1912.

Table I indicates the overhead cover and the stocking of planted pine before cutting:

TABLE I
BASAL AREAS PER ACRE OF OVERHEAD COVER AND
NUMBER OF PLANTED WHITE PINES

Plot No.	White pine Sq. ft.	Norway pine Sq. ft.	Red oak Sq. ft.	White oak Sq. ft.	Aspen Sq. ft.	Red maple Sq. ft.	Total Sq. ft.	No. of planted white pine per acre
1	7.298	1.295	18.440	18.917	47.032	10.094	103.076	1,141
2	6.721	0.568	29.957	11.356	39.138	8.709	96.449	1,100
3	2.056	0.419	38.322	20.126	19.530	6.673	87.126	1,249
4	2.898	2.460	42.844	21.240	13.535	2.908	86.327*	1,114
5	5.029	2.753	27.928	22.098	9.407	4.743	71.958	1,002

* One jack pine, in Plot 4, is omitted from the table, but is included in the total basal area.

Density of crown cover and composition were not uniform over the entire area chosen for the study, but represented fairly average conditions, as found in such second growth in that locality. In general, the density of cover increased from east to west, partly because of a heavier degree of stocking on the west portion and partly because of a larger percentage of red maple and natural second-growth white pine in the mixture.

The area was subdivided into five plots, each of three fourths of an acre, except Plot 5, which covered a full acre. Each plot was surrounded by an isolation strip one-half chain in width. The plots were fairly uniform in overhead cover, except that oaks predominated strongly on the east one third to one half of the several plots, the percentage being greatest on Plot 5 and least on Plot 1. The amount of aspen was considerably higher on the west portion of Plots 1 and 2 than on any of the others. Plots 3 and 4 had much smaller amounts.

Table II indicates the number of planted pines by height classes on the several plots before cutting:

TABLE II
NUMBER OF PLANTED WHITE PINES PER ACRE BY
HEIGHT CLASSES IN 1928

Height class Feet	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5
1	246	261	168	251	146
2	251	256	341	337	221
3	200	163	305	265	206
4	136	152	209	140	153
5	93	104	117	58	118
6	69	76	60	34	94
7	40	43	29	15	32
8	31	15	13	6	18
9	21	21	4	8	9
10	13	8	1	...	5
11	17	1	1	...	...
12	11	...	1	...	...
13	5	...	...	...	...
14	5	...	...	...	...
15	3	...	...	...	...

The majority of the pines are below the five-foot height class on all plots. The percentages of trees below the five-foot class run

as follows: Plot 1, 73.0; Plot 2, 75.6; Plot 3, 81.8; Plot 4, 89.1; Plot 5, 72.4.

The naturally grown white pine was restricted to a narrow strip which ran across all the plots in a north and south direction. Large clumps of witch hazel and serviceberry were abundant on portions of the area and materially increased the actual density of overhead cover wherever they occurred. The ground cover was mostly thin and composed of bracken, wintergreen, huckleberry, and grass. Grass was considerably heavier under the oak portion of the stand and was practically lacking under red maple and the dense clumps of brush. The effect of variations in density upon the past growth of the underplanted white pine was very pronounced. Where high density prevailed, the height of the white pine was mostly less than one foot, while in more open portions of the stand it varied between four and ten feet.

Fife Lake Plots

The second series, of six plots, all of which lie on top of a broad ridge, on land that is practically level, was established by the School of Forestry and Conservation in 1929 on the Fife Lake State Forest in Grand Traverse County. The stand consisted principally of red and white oaks and red maple. There were occasional small groups of aspen, a few white and Norway pines on Plot 1, and a small number of sugar maple and black cherry. The distribution of the trees was somewhat irregular, with a number of small openings scattered throughout. These openings had an area of about one to three square rods. Aside from the openings, the density of cover was about eight tenths. The amount of underbrush was very small, consisting of a few clumps of serviceberry. Under the denser portions of the stand the ground cover of grass, wintergreen, blueberry, and bracken was rather thin. In the openings there was a heavy cover of bracken and sweet fern.

The original timber was cut about 1884. Counts made on the stumps of trees removed in the release cutting showed that the age of the second growth ranges from about 20 to 40 years. Several veteran oaks remained on Plots 4, 5, and 6.

The white pine was underplanted in the spring of 1919. Except around the edges of openings growth has been very slow. In the central portions of the openings the planting failed to catch. This

demonstrates the need for overhead cover in securing establishment of white pine under existing conditions of climate and soil.

Table III shows the character of overhead cover and the number of planted pines present at the time the study was initiated:

TABLE III

BASAL AREAS PER ACRE OF OVERHEAD COVER AND NUMBER OF
PLANTED WHITE PINES

Plot No.	White pine Sq. ft.	Norway pine Sq. ft.	Red oak Sq. ft.	White oak Sq. ft.	Aspen Sq. ft.	Red maple Sq. ft.	Cherry Sq. ft.	Sugar maple Sq. ft.	Jack pine Sq. ft.	Total Sq. ft.	No. of planted white pines
1	0.385	2.387	15.019	17.233	4.084	15.116	0.292	0.047	....	54.563	664
2	0.165	0.354	17.874	28.940	0.547	9.182	0.512	....	....	57.574	712
3	....	0.007	20.013	26.463	1.262	9.261	1.272	0.008	0.009	58.295	760
4	....	....	7.834	34.506	0.871	3.451	0.986	....	0.067	47.715	790
5	....	....	17.126	18.018	3.176	8.430	....	0.016	....	46.766	784
6	....	....	12.988	17.070	2.176	15.730	0.170	0.022	....	48.156	756

Table IV gives the number of pines by height classes on the several plots before cutting:

TABLE IV

NUMBER OF PLANTED WHITE PINES PER ACRE BY
HEIGHT CLASSES IN 1929, FIFE LAKE PLOTS

Height class Feet	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6
1	411	386	483	341	462	468
2	188	244	214	297	242	220
3	53	60	56	106	76	52
4	10	16	6	37	4	14
5	2	4	0	9	0	2
6	0	2	1	0	0	0
Total	664	712	760	790	784	756

Birch Lake Plots

Another set of release-cutting plots was established in 1931 in the Birch Lake plantation of Norway pine on the Superior National Forest in northeastern Minnesota by the Lake States Forest Experiment Station. This plantation, slightly over 100 acres in extent,

was started in 1915 and 1917 on a site which originally was said to have yielded some 50,000 board feet per acre of Norway and white pine timber. After cutting, the area was burned several times. The last fire, which burned off all vegetation, had occurred the

TABLE V
NUMBER OF TREES PER ACRE BY HEIGHT CLASSES AFTER CUTTING

Plot No.	Height classes in feet									
	5	10	15	20	25	30	35	40	45	Total
25 (check)										
Aspen.....	..	4	40	116	164	300	288	168	16	1,096
Norway pine...	..	72	116	144	84	8	...	...	..	424
Others.....	..	..	28	64	...	...	...	...	..	92
Total.....	..	76	184	324	248	308	288	168	16	1,612
24 (light release)										
Aspen.....	..	..	80	104	160	168	172	24	..	708
Norway pine...	4	40	72	92	108	4	...	...	..	320
Total.....	4	40	152	196	268	172	172	24	..	1,028
26 (heavy release)										
Aspen.....	..	..	8	8	8	40	52	...	..	116
Norway pine...	..	64	132	112	68	...	...	...	..	376
Total.....	..	64	140	120	76	40	52	...	..	492

TABLE VI
BASAL AREA PER ACRE OF PLOTS BEFORE CUTTING

Plot No.	Norway pine Sq. ft.	Aspen Sq. ft.	Others Sq. ft.	Total Sq. ft.
25 (check)	25.22	63.21	0.96	89.39
24 (light release).....	22.62	44.17	...	66.79
26 (heavy release)	20.30	41.24	0.82	62.36

year previous to planting. This, then, was an area where the planted trees had an even start with any broad-leaved species that might come in later. The soil is a gravelly and sandy loam of good quality

— much better than that of either of the Michigan areas. Various ages of transplant stock were used over the whole plantation, but on the area concerned in this report 1-1 stock was planted. All trees were planted by the deep-hole method, with a spacing of 8×8 feet, or about 680 pines to the acre.

Good survival was obtained, and two years after planting nearly 85 per cent of the trees were still living. No care, however, was given the young trees, and in 1931, when a survey of 10 per cent of the plantation was made, it was found that aspen was seriously crowding the planted pine trees and had overtopped many of them. The tops of many pines were being deformed by the whipping of the aspen. At this time, although pine still predominated on one fifth of the area, aspen and brush had completely claimed one fourth of the plantation, and over one half was a mixture of aspen and pine.

In the area of mixed aspen and pine, aspen and other broad-leaved trees numbered about 1,200 per acre and Norway pine about 375 per acre. The Norway pine averaged a little over 3 inches in diameter, but ranged in diameter from 1 to 5 inches and in height from 9 to 28 feet. The average height of the aspen was about 30 feet, but many trees were 40 feet tall and a few were 45 feet. They occurred in groups within which the pines were nearly all suppressed. Around the edges of these groups, however, most of the pines, although crowded, were still thrifty.

CUTTING METHODS

A number of cutting methods were employed to determine which one would give the best results when all factors were taken into account, i.e. the effect upon the growth of pine, the cost of cutting, and the possible financial returns.

The methods used on the Higgins Lake plots were as follows:

- Plot 1. — A heavy commercial cut, which removed all hardwoods with a diameter breast-high of four inches and better. All clumps of witch hazel and serviceberry were also cut.
- Plot 2. — A light commercial cut. All trees over 7 inches in diameter and all large clumps of brush were cut.
- Plot 3. — The control plot. No cutting was done.
- Plot 4. — Cutting of all brush and small, unmerchantable, suppressed

trees. In addition, the lower branches of the larger trees that threatened mechanical damage to the tops of white pine were pruned.

Plot 5. — Clear-cutting, except for 14 oaks with high, small crowns, 1 thirteen-inch Norway pine, and 5 white pines.

On the Fife Lake Plots a somewhat different combination of cutting methods was used, as follows:

Plot 1. — Everything cut but 92 of the largest and best oaks and the five large pines that were present.

Plot 2. — The control plot for Plots 1, 3, and 4. Nothing was cut.

Plot 3. — A heavy thinning from below, which left only dominant and codominant trees. Of these, 127 were white oak, 109 red oak, 20 red maple, and 4 aspen.

Plot 4. — A thinning designed primarily to aid the growth of the young oak, with an incidental, partial release of the white pine. This type of cutting was adopted because of the large percentage of small, unmerchantable oak on the plot, which would be expensive to cut and would yield no return.

Plot 5. — A thinning to favor the growth of oak, since the bulk of the trees were below five inches in diameter.

Plot 6. — The control plot for Plot 5. No cutting was done.

VOLUME CUT AND COSTS

All wood was piled after cutting and the number of stacked cubic feet in each pile determined. From these figures the number of standard 4' $\times$ 4' $\times$ 8' cords was computed for each plot. The costs

TABLE VII

HIGGINS LAKE PLOTS

Plot No.	Total volume cut Cords	Total cutting time Man-hours	Total cost
1	22.7	133.5	\$66.75
2	15.8	110.0	55.00
3	....	....	....
4	....	10.5	5.25
5	13.7	126.5	63.25

given in Tables VII and VIII are based on a wage of fifty cents per hour in the case of the Higgins Lake plots and \$3.50 per eight-hour day on the Fife Lake plots. These were the current wages in 1928 and 1929. Cutting time includes the time required for felling, limbing, lopping and scattering slash, bucking, and piling.

It should be noted that the figures given in Table VII are all on a per acre basis. The cost per cord for Plot 5 was higher than that for Plot 1, chiefly because so much small, unmerchantable material had to be cut that was not included in the volume.

TABLE VIII

FIFE LAKE PLOTS

Plot No.	Total volume cut per acre Cords	Total cutting time per acre Man-hours	Total cost per acre
1	8.34	85.0	\$37.19
2	....	....	....
3	4.07	48.0	21.00
4	2.60	34.5	15.09
5	2.28	47.0	20.56
6	....	....	....

The plots listed in Table VIII are one acre each, except Plots 5 and 6, which are one-half acre. The smallness of the volumes cut is due partly to the methods of cutting but more to the small size of many of the trees that were removed.

Birch Lake Plots

Two degrees of release cutting were tried on the Birch Lake area. Approximately an acre was devoted to each type of cutting. Sample plots of one-fourth acre were established on each cutting area. On the first (Plot 24) 380 aspens per acre were cut or 40 per cent of their basal area. The purpose was to afford a complete release of the thriftier intermediate pines, but no direct attempt was made to save the smaller and the more suppressed ones. The very largest pines apparently needed little or no help.

On the second plot (Plot 26) a more drastic release was made. The intention here was to release every planted tree. This resulted in the cutting of 800 aspens per acre or nearly 90 per cent of their

basal area. Although the number was more than twice that cut on the first plot, the basal area removed was almost exactly double that of the former. A third plot (Plot 25) was left uncut for comparison. This check plot was fairly representative of the other two plots before cutting took place, but contained somewhat fewer aspens and more pines than the other plots.

At Birch Lake the light release required three and one-half hours of labor per acre and the heavy release six and one-fourth hours per acre. This did not include time spent in lopping down the slash. The man who did the work probably accomplished more than the average laborer can be expected to do, but no time was allowed for supervision. So much more reliable figures for large areas are now available for work of a similar character by both NIRA workers and CCC camps that the cost data from these small plots are probably not highly indicative of what such work costs. On the whole they are probably low.

No market existed for any of the material cut, and it was merely lopped down so that it would lie fairly close to the ground.

MEASUREMENTS AND OTHER DATA

Before the trees on the several Michigan plots were measured those to be cut were blazed, and the hardwoods to be left were tagged, as well as the underplanted white pine. All trees on each plot were measured in one operation, being taken in the order that they occurred on the ground, so that their positions on the tally sheet indicate their actual relative positions to one another in the stands.

The heights of all underplanted white pines were measured with a graduated pole. Diameters of these pines were measured only when the diameter breast-high was of appreciable size. Diameters of all hardwoods were measured and the heights estimated in five-foot classes, with a Forest Service hypsometer used as a check. The crown class and the relative crown width were recorded, and the tally sheets showed whether or not a given tree was to be cut.

Subsequent measurements of the current height growth of the underplanted white pines were made on the Michigan plots to determine how soon any stimulation in growth occurred after the cutting. On the Higgins Lake plots in 1929 the measurements covered the growth for the years 1926, 1927, 1928, and 1929, with the growth for each year recorded separately. The growths for 1930 and 1931

were taken in those years. Similar measurements were taken on the Fife Lake plots for 1929, 1930, and 1931.

The trees removed on the Birch Lake plots were tallied by diameters, and sufficient heights were measured to obtain a good height-diameter curve. Trees which remained after cutting on the sample plots were all tagged and measured for diameter at breast height to the nearest tenth-inch. Heights of all pines were measured with a pole to the nearest tenth-foot. Sufficient heights of remaining aspen trees were measured to obtain a good height-diameter curve. The shorter trees were measured with a graduated pole and the taller ones by Abney level. Three years after cutting, in July, 1934, all numbered trees were remeasured for both height and diameter, and general observations were made.

A record has been kept of all pines broken by fallen trees, buried in slash, or damaged in any way later, on both the Higgins Lake and the Fife Lake plots.

RESULTS OF CUTTING

1. *Upon character of remaining stand*

The stand left upon Plot 1 of the Higgins Lake series was very irregular. Considerable portions were cut practically clear, exposing the pine completely, while the central part still retained considerable density, because of the presence of a number of rather large white pines.

The density of the western end of Plot 2 was changed very little, and at no place was the stand opened to the extent that it was on Plot 1.

The principal change on Plot 4 was in removing the danger of mechanical damage from overhanging limbs, small hardwoods, and brush to the white pines for some years to come. The remaining density was so great that a number of hardwood trees in the lower crown classes have died of suppression during the past six years.

On Plot 5 the pines were fully exposed to all intents and purposes, since the very small number of trees left afforded little shade.

In the Fife Lake series Plot 1 was nearly clear-cut, so that most of the pines were fully exposed. Others, those that were under the crowns of the oaks left, were given a greatly increased amount of light.

The stands left on Plots 3, 4, and 5 were uniformly distributed, except where openings in the original stand caused irregularities.

2. Upon height growth and vigor of underplanted white pine

The most striking response to the cutting upon the underplanted white pine was on the clear-cut plot at Higgins Lake. The great increase in luxuriance and density of foliage on the pines was evident to the most casual observer by the end of the second year. On the more heavily cut portions of Plot 1 the pines showed the same reaction. On none of the other plots, in either series, was any such marked change in general vigor apparent.

The height growth after cutting is shown for both series in Tables IX and X.

TABLE IX
AVERAGE HEIGHT GROWTH, 1928-33
HIGGINS LAKE PLOTS

Height class Feet	Plot 1		Plot 2		Plot 3		Plot 4		Plot 5	
	No. trees	Feet	No. trees	Feet	No. trees	Feet	No. trees	Feet	No. trees	Feet
1	123	1.4	149	1.2	120	0.6	185	0.7	72	3.0
2	154	2.2	173	2.2	250	1.1	274	1.4	160	3.6
3	141	2.9	117	2.7	228	1.7	200	1.7	160	4.0
4	96	3.3	112	3.3	153	2.0	108	2.0	119	4.5
5	72	3.8	75	3.2	88	2.6	37	2.4	90	4.9
6	49	3.5	56	3.9	44	2.6	23	2.7	66	5.3
7	30	4.1	31	4.2	21	3.5	9	2.9	27	5.3
8	22	4.3	9	5.2	8	3.1	3	3.2	19	5.4
9	16	5.1	15	4.9	5	3.8	5	3.5	7	5.9
10	8	6.0	5	6.2	1	2.9	...	...	5	5.9
11	14	5.8	1	4.1	1	4.5	...	...	...	...
12	7	6.6	...	...	1	4.6	...	...	...	...
13	4	5.8	...	...	...	...	...	...	...	...
14	4	7.1	...	...	...	...	...	...	...	...
15	1	6.8	...	...	...	...	...	...	...	...
Total Average	741	2.9	743	2.6	920	1.6	844	1.5	725	4.3

The growth on the three Higgins Lake plots that were cut severely enough to produce an appreciable change in cover conditions has shown a marked increase over that on the control plot, with growth on the clear-cut plot the best of all. The same sort of response has occurred on all the Fife Lake plots, except that the most heavily cut plot (Plot 1) has shown it to a smaller degree than might have

been expected on the basis of relative severity of cutting. This has been due largely, no doubt, to the rapid growth of red maple sprouts that resulted in the rather early overtopping of many pines on this plot.

A remarkable response in diameter growth took place in the Norway pines released by the cutting at Birch Lake. The growth

TABLE X
AVERAGE HEIGHT GROWTH, 1929-34
FIFE LAKE PLOTS

Height class Feet (1929)	Plot 1		Plot 2		Plot 3		Plot 4		Plot 5		Plot 6	
	No. trees	Feet	No. trees	Feet	No. trees	Feet	No. trees	Feet	No. trees	Feet	No. trees	Feet
1	338	1.45	368	0.91	415	1.27	311	1.28	204	0.99	199	0.72
2	175	2.06	237	1.55	205	2.04	286	1.97	113	1.59	98	1.28
3	52	2.58	56	2.02	54	2.36	101	2.42	38	2.09	24	1.88
4	10	3.06	16	2.55	6	2.57	37	2.80	1	2.10	6	2.27
5	2	3.75	4	2.35	...	...	6	2.90	...	...	1	3.30
6	...	...	2	2.45	1	2.90	...	...	...	...	...	...
Total Average	577	1.78	683	1.27	681	1.60	741	1.79	356	1.27	328	1.01

on the lightly treated plot was over one and one-half times as great as that on the check plot. The growth on the heavily released plot, however, was found to be nearly two and one-half times as great as that on the check plot. Diameter growth was thus almost directly proportional to the degree of release.

The diameter growth by crown classes is also of decided interest. At the time the cutting was done it was felt that the suppressed trees (planted for over 16 years) could not be saved and that they would not respond to the cutting but would succumb from exposure. On the contrary, they responded the best of all and grew almost as fast as the dominant and the intermediate trees. Although no attempt was made to release suppressed trees on the lightly treated plot they responded by reason of the general release given to larger trees. The diameter growth of these suppressed trees on the heavy release cutting was over three times as great as that on the check plot.

The response in height growth was not nearly so marked, and the average tree on the lightly treated area did better than the

average on the plot completely released. The intermediate trees made a better height growth than those of any other class, but the greatest response to the cutting was again in the suppressed trees. The height growth of the dominant trees — trees which already had their crowns free when the cuttings were made — on the lightly released area was almost exactly the same as that on

TABLE XI
BASAL AREA GROWTH PER ACRE OF RESIDUAL STAND
HIGGINS LAKE PLOTS

Plot No.	Aspen		Red maple		Red oak		White oak		Norway pine		White pine		Total	
	Sq. ft.	Per cent	Sq. ft.	Per cent	Sq. ft.	Per cent	Sq. ft.	Per cent	Sq. ft.	Per cent	Sq. ft.	Per cent	Sq. ft.	Per cent
1	0.558	6.0	0.835	4.8	1.535	5.1	1.023	4.7	0.461	5.7	1.550	4.8	5.832	4.9
2	3.003	6.6	1.136	6.2	4.389	6.9	1.638	5.1	0.200	7.2	2.278	5.5	12.644	6.2
3	2.104	2.6	1.214	3.0	7.129	3.4	1.574	1.7	0.008	1.1	0.403	3.6	12.432	2.9

TABLE XII
BASAL AREA GROWTH PER ACRE OF RESIDUAL STAND
FIFE LAKE PLOTS

Plot No.	Aspen		Red maple		Red oak		White oak		Norway pine		White pine		Total	
	Sq. ft.	Per cent	Sq. ft.	Per cent	Sq. ft.	Per cent	Sq. ft.	Per cent	Sq. ft.	Per cent	Sq. ft.	Per cent	Sq. ft.	Per cent
1		...		...	2.824	8.2	2.088	5.9	0.473	3.7	0.139	6.4	5.524	6.5
2		...		...	3.052	3.2	2.353	1.6	0.049	2.6	0.051	5.5	5.505	2.2
3	0.016	0.7	0.935	11.2	3.716	4.4	1.645	1.9	....	...	....	...	6.312	3.4
4		...	0.566	9.0	1.980	5.3	6.594	4.6	....	...	....	...	9.140	4.9
5		...		...	4.406	5.4	4.164	5.2	....	...	....	...	8.570	5.3
6		...		...	4.182	5.7	3.438	3.7	....	...	....	...	7.620	4.6

the check plot. The height growth of the dominant trees on the area heavily cut was less than that on the other two plots.

The data for height and diameter growth after cutting express very well the reaction upon the released pines. The general tendency was toward a marked increase in stockiness rather than an increase in height. The observation that many spindly trees put on thicker foliage supports this conclusion. Many trees with deformed tops put on definite leaders. No cases of injury to the pines as a result of exposure by cutting were noted.

The slash left on the ground, although not lopped very thoroughly, did not seem to present any fire hazard three years after cutting. The finer twigs had mostly fallen off and the stems were beginning to decay.

3. *Upon basal area growth of uncut overhead cover*

The growth in basal area of the residual overhead cover on the various plots of the Higgins Lake series is shown in Table XI; that for the Fife Lake series, in Table XII. This growth is for the first five-year period after cutting. These figures are of particular interest in the case of Fife Lake Plots 3, 4, and 5, since because of the type of cutting employed they indicate better than the other plots what may be expected of hardwoods on a site of this character.

It is noteworthy that the percentage of growth is greater on all the cut plots than on the corresponding control. This is also true of the total growth in square feet of basal area, except on Plot 1 of the Higgins Lake series, which had most of the dominant trees removed. Since there was practically no change in the crown density of Plot 4, Higgins Lake, the figures for this plot are not given.

4. *Upon development of sprouts*

On the Birch Lake plots aspen suckers came up prolifically the year following cutting. Three years afterward, however, none seemed sufficiently tall or vigorous to overtake even the smaller pines.

The situation was quite different on both the Higgins Lake and the Fife Lake plots. At Higgins Lake aspen suckers were numerous only on the more heavily cut portions of Plots 1 and 2. Because of the smallness of many of the pines the aspens overtopped them and needed to be cut by the fourth year after the original cut. At Fife Lake there were so few aspens on the plots that suckering has been negligible. Red maple sprouts have been much more serious than aspen suckers at both Higgins Lake and Fife Lake. Maple sprouts have grown very rapidly and have again overtopped many of the pines. They should have been cut the third year in order to keep the pines in an open position. It is precisely on these portions of the plots that the pine is most in need of release, because wherever maple occurred in the original cover the pine was most badly suppressed.

A number of the oak and maple stumps at Higgins Lake were

treated with creosote to prevent sprouting. This treatment was effective with oak, but only partially so with maple.

5. Upon various forms of damage

Cutting operations on both the Higgins Lake and the Fife Lake plots resulted in some damage to both pines and hardwoods. Some pines were broken by falling trees; others were buried by slash and killed. Many badly suppressed pines on heavily cut plots died from the sudden exposure. Another effect of cutting was a heavy increase in weevil damage on the clear-cut plot at Higgins Lake. Weevil

TABLE XIII
MORTALITY AND INJURY
HIGGINS LAKE PLOTS

Plot No.	Height class Feet	Number of trees				
		Dead	Damaged			
			Weevil	Logging	Other	Total
1	1	47	..	..	5	5
	2	27	2	2	7	11
	3	7	..	3	8	11
	4	3	..	..	8	8
	5	..	1	..	4	5
	6	..	2	1	2	5
	7	..	..	..	1	1
	8	..	..	1	4	5
	9	..	..	..	..	..
	10	..	2	..	..	2
	14	..	1	..	..	1
	Total	84	8	7	39	54
2	1	42	1	2	..	3
	2	14	2	..	3	5
	3	4	..	..	4	4
	4	2	..	1	5	6
	5	2	1	1	1	3
	6	1	..	..	2	2
	7	..	..	2	1	3
	8	1	1	..	..	1
	9	..	..	..	..	..
	10	..	1	..	..	1
	Total	66	6	6	16	28

TABLE XIII (Continued)

MORTALITY AND INJURY
HIGGINS LAKE PLOTS

Plot No.	Height class Feet	Number of trees				
		Dead	Damaged			
			Weevil	Logging	Other	Total
3	1	6	2	..	5	7
	2	5	5	..	6	11
	3	1	3	..	6	9
	4	3	2	..	3	5
	5	1	..	..	3	3
	6	2	..	..	..	..
	7	..	..	..	..	..
	8	..	1	..	..	1
	Total	18	13	..	23	36
4	1	8	1	..	6	7
	2	2	3	..	2	5
	3	..	2	..	..	2
	4	..	2	..	..	2
	5	..	..	..	..	..
	6	..	..	..	..	..
	7	..	..	..	..	..
	8	..	1	..	..	1
	Total	10	9	..	8	17
5	1	62	8	3	..	11
	2	34	25	1	3	29
	3	15	25	5	..	30
	4	6	26	2	1	29
	5	2	18	1	2	21
	6	2	4	4	..	8
	7	..	5	..	..	5
	8	..	1	..	..	1
	9	..	1	..	..	1
	Total	121	113	16	6	135

damage has been slight on all the Fife Lake plots, and there is no apparent correlation between its occurrence and the degree of cutting. Grazing cattle have broken more pines on the Higgins Lake plots than were broken in logging. At Fife Lake injury to some pines has occurred subsequent to logging, probably caused by berry pickers

and others who have walked through the plots. Most of the logging breakage occurred on pines over three feet in height. Smaller pines were bent instead of broken and recovered when released. On the other hand, the smaller pines are more likely to be buried in slash and not discovered for release. This source of damage is more serious when cutting is done while the hardwoods are in leaf.

Though a few of the smaller hardwoods were broken in logging, more serious damage was done by sunscald on aspen and red maple. This occurred only on the heavily cut portions of Plots 1 and 2 at Higgins Lake.

The actual number of pines damaged on the Higgins Lake plots is shown in Table XIII; on the Fife Lake plots, in Table XIV.

CONCLUSIONS

Release cuttings in mixed stands of aspen and young Norway pine are distinctly worth-while cultural operations. The young pine, even when badly suppressed by taller and more vigorous aspen, respond immediately to release in almost direct proportion to the degree of cover removal. Suppressed trees benefit most by such cuttings. The early reaction of the trees released takes the form of an increased stockiness, i.e. diameter growth increases at a higher relative rate than does height growth.

On most dry, sandy sites white pine is benefited during its early years by an overhead cover, but later growth is retarded. After becoming established it should be released in order to secure satisfactory growth. Its response to such a release is prompt and roughly proportional to the degree of release. However, a clear-cutting of the overhead cover is undesirable because of the danger of increasing damage from weevils. Moreover, if the pine has been left so long as to become badly suppressed it is likely to die if uncovered too suddenly.

Underplanting of white pine on spots occupied by maple and junberry is inadvisable because of the prolific sprouting of these species after cutting.

Heavy stands of aspen when clear-cut produce a mass of suckers that offer worse competition to the pine than does the original stand, unless the pine is large enough to keep ahead. Partial cutting will probably lessen the production of suckers very materially, but follow-up release cuttings will be necessary if the pine is small. Another

TABLE XIV
MORTALITY AND INJURY
FIVE LAKE PLOTS *

Plot No.	Height class Feet	Number per acre			
		Dead	Damaged		
			Weevil	Other	Total
1	1	54	8	12	20
	2	8	4	1	5
	3	1	..	..	..
	Total	63	12	13	25
2	1	1	2	15	17
	2	2	5	2	7
	3	1	3	..	3
	Total	4	10	17	27
3	1	42	4	22	26
	2	5	2	2	4
	3	1	..	1	1
	Total	48	6	25	31
4	1	7	7	16	23
	2	6	2	3	5
	3	2	3	..	3
	4	..	..	..	..
	5	..	1	..	1
	Total	15	13	19	32
5	1	22	4	27	31
	2	4	4	6	10
	3	..	..	..	..
	4	..	2	..	2
	Total	26	10	33	43
6	1	16	16	43	59
	2	16	6	1	7
	3	..	2	2	4
	4	..	2	..	2
	5	..	..	..	..
	Total	32	26	46	72

* Missing trees are tallied as dead.

method of reducing trouble from root suckers is to wait until the aspen is nearly mature before cutting.

Planting white pine under oak with subsequent release cutting is liable to be an expensive undertaking unless the overstory can be disposed of at a price sufficient to offset at least a large part of the cost of cutting. Oak stands of merchantable size and of medium, but rather uniform, stocking offer the best opportunity for successful underplanting with pine and subsequent release cutting of a partial character. Large openings in such stands should not be planted with white pine, since attempts of this sort have usually failed.

When a fully stocked oak stand is to be underplanted, it should first be opened as much as possible, leaving only enough cover to protect the site and prevent serious trouble from the white pine weevil. Cutting and subsequent underplanting in stands of this kind should be delayed until they have reached merchantable size. The first cut should remove as many as possible of the largest-crowned trees in order to reduce damage to the pines in later cuttings.

Where stands are now underplanted, and release cutting seems desirable, the cut should be made as soon as possible to reduce damage from breakage. In such cases cutting should be done when the hardwoods are bare to reduce the danger of killing pines by burying them with slash.

When red oak is removed in a release cutting, treatment of the stumps with creosote will practically eliminate sprouting and the necessity for later cuttings. White oak that is forty years old or more has little or no sprouting ability in the northern portion of the Lake States.

Lopping and scattering of slash have proved to be satisfactory in all cases.

THE GEOGRAPHIC FACTOR IN THE DISTRIBUTION, TRENDS, AND PEAKS OF THE POPULATION OF PUERTO RICO,
1900-1930

LYMAN D. BOTHWELL

GEOGRAPHY AND CLIMATE

THE density and the distribution of population in Puerto Rico has been conditioned by the geographic factor. This island, which is 100 miles in length and 36 in width and almost rectangular, with its longer axis lying east and west, is well within the tropics, since 18° N. Lat. almost coincides with the southern coast. It is part of the great volcanic range that constitutes the Antilles. Traversing it from east to west (22 miles from the northern coast and nearly 14 miles from the southern coast) is a broken range of low mountains, which, toward the eastern corner of the island, trends to the northeast, where it enters the sea. It ranges in elevation from 2,000 to 3,000 feet, with occasional summits slightly above 3,000 feet and gaps slightly below 2,000 feet. From its crest the island slopes northward in broad undulations, deeply cut by streams that give most of the interior a steep, hilly surface, gradually becoming more level until near the coast it spreads into broad, level playas, which extend up into the valleys of the larger rivers, averaging six miles in width on the northern coast and three on the southern coast. This range, which is the water divide, is flanked on the north and the south by limestone deposits dissected by erosion into foothills. On the northern slope the rivers are long, slow, and meandering. On the southern they are steep and short, and because the south flank has more of a limestone subsoil it is usually overdrained. In this humid climate erosion has been so active and so long continued that there is no trace of an original crest, and the unaltered rock is often covered to a depth of 100 feet.¹

¹ *Commercial Porto Rico in 1906*, Department of Commerce and Labor, p. 5. Washington, 1907.

Puerto Rico has a uniform climate and a slight range of temperature. The only distributional differences in temperature are due to altitude. Lying in the tropics, the island is within the region of the northeast trades, which blow with great regularity. The annual temperature ranges from 75° to 85°. The annual rainfall averages 55 inches on the north coast and about 30 on the south. Here irrigation is necessary, since the rivers are steep and short and, as is usual in limestone areas, much of the drainage is underground.

Some of the topographical characteristics are the small flat valleys in the mountains and the large, depressed drainage basin of the Loiza and Rio Grande, where erosion has forced the mountain mass back almost to the south shore. The coast is low (alluvial and recent lagoonal), and for the most part simple, with few good harbors, the best of which is that of San Juan on the north coast.

POPULATION

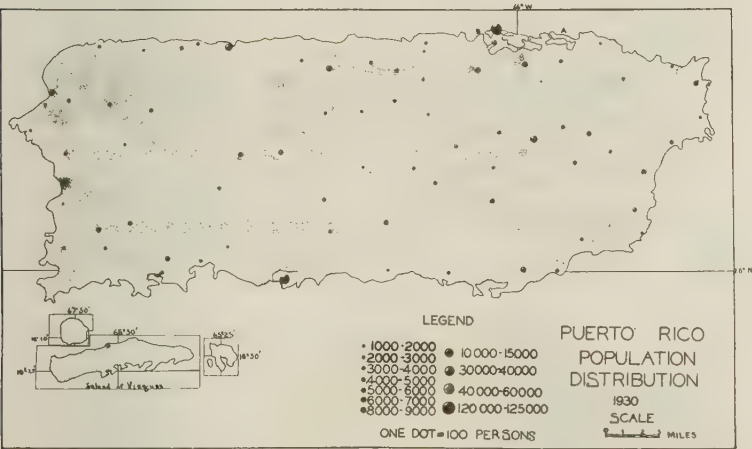
Puerto Rico is not only densely, but also relatively evenly, populated. In 1930 the urban population was 403,796 in 73 towns of over 1,000, and the rural population 1,140,117. The density, which in 1900 was 277 persons per square mile, increased to 450 per square mile by 1930, and the total population increased from 953,243 in 1900 to 1,543,913 in 1930. This great density is to be explained in terms of the fertile soil, the equable climate, and the abundant rainfall, as well as in terms of the cultural pattern. The salient point in population is a continuous, uniform growth of nearly 2 per cent per annum since 1900. At this rate the population will double itself in about forty-four years. This is slower than are most known rates of population doubling, as computed by Mark Jefferson.² No municipality has a density twice that of any other municipality, which is evidence of the even distribution due to intense cultivation.

If we examine the map of population distribution for 1930 (Map 1), we see that the northern half of the island is more densely populated than the southern half. Here the effect of the more equable climate, the more abundant rainfall, and the gently sloping area on the population distribution is apparent.

Owing to the fact that the coast is a rich alluvial plain varying in width from 3 to 7 miles the population here is denser than that in the interior, which is a broken and steep group of foothills.

² Jefferson, Mark, "Looking Back at Malthus," *Geog. Rev.*, 15: 182. 1925.

The accompanying maps show the distribution of population in 1930 (Map 1), as well as the peak (Map 2) and the trends (Map 3) by *barrios* (wards), which are the smallest civil divisions. There are 695 of these wards with an average area of 5 miles. Map 1 includes



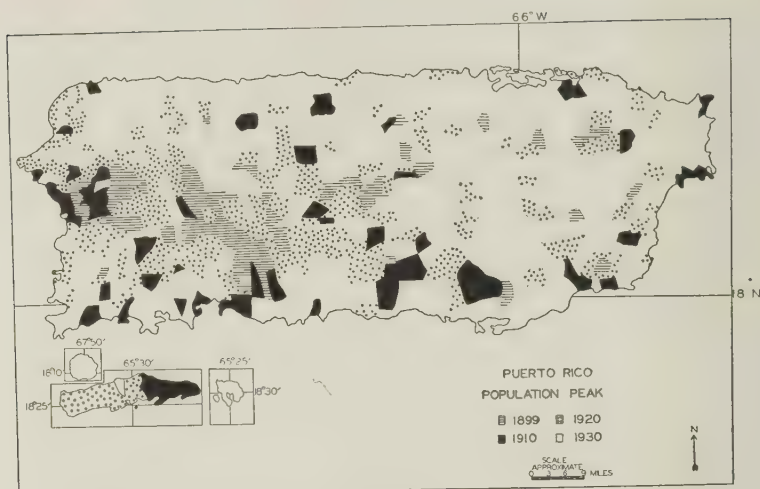
MAP 1

rural and urban population (towns of over 1,000 inhabitants); Maps 2 and 3 show only rural peaks and trends (San Juan included).

Examining Map 1 we see that the density is more pronounced than in 1900, and that there has been a decided growth in the size of the towns (represented by spheres), and a shift of density from the interior to the coast due to failure of the coffee industry, and a general shift from west to east and from south to north which can be attributed to urbanization and the increasing importance of sugar cane and citrus fruits in the wide alluvial northern plains, as shown by the export figures in the following table:

	1900	1930
Sugar	\$3,750,000	\$53,670,000
Citrus fruits ...	250,000	8,000,000
Total	\$4,000,000	\$61,670,000

The density increase in the southeast is noticeable and is due to the large irrigation projects which have been finished in that region since 1900. The northwest, which in 1900 was more densely popu-



MAP 2



MAP 3

lated than the northeast, is less densely populated in 1930, owing to the decline of the coffee industry and urbanization in the northeast. The whole depressed drainage basin of the Loiza and the Rio Grande has shown a large increase, both rural and urban, due to the rapid growth of the tobacco industry, exports of which were \$645,000 in 1900 as compared to \$12,000,000 in 1930. The two wards, to the east and the west of San Juan (the largest urban center), labeled *A* and *B*, respectively, show a marked population gradient, as in the Hackensack Meadows of New Jersey,³ where the land is low and swampy.

The urban population (consisting of the population of towns of 1,000 persons or over) has increased much faster than the rural, from 210,983 persons in 60 towns in 1900, to 403,796 persons in 73 towns in 1930, an increase of 91.5 per cent, while the rural population increased from only 742,300 to 1,140,117 persons, an increase of 397,917, or only 54 per cent. If we use the United States census classification of "urban" (2,500 persons or over), the urban population increase in the same period is 208 per cent, and the rural population increase only 37 per cent. Both these methods show a rapid urban growth, which is in part due to the extension of the road system. In 1900 there were 285 miles of improved road, whereas in 1930 there were 1,100 miles. It is also in part due to the increase in the average land holding. In 1900 the average farm was 12.3 acres; in 1930, 37.3 acres. In 1900 there were 39,021 farms and 478,000 acres in cultivation, whereas in 1930 the acreage had increased fourfold and the number of farms had increased only by 34 per cent, that is, from 39,021 to 52,965. In 1900 Puerto Rico was essentially the land of the small farmer; in 1930 it was the land of the large landowner, over half of the land in cultivation being owned by 100 persons or corporations. The resulting landless have gravitated to the cities, as the growth of slums vividly testifies.

The population density in 1900 was 277 persons per square mile, and this had increased to 450 by 1930 and to 485 by 1935, even though, according to estimates, 158,000 Puerto Ricans emigrated to the United States and South America between 1910 and 1930.⁴ It

³ See Wolfe, A. B., "Some Population Gradients in the United States," *Geog. Rev.*, 18: 291-301. 1928.

⁴ *Bulletin of Bureau of Foreign and Domestic Commerce*, No. 785, p. 2. Washington, D.C., 1932.

should be pointed out that this increase is due more to a decrease of the mortality rate, than to an increase in the birth rate. Population increased from 1899 to 1910 at the rate of 15,000 persons per annum; from 1910 to 1920 at the rate of 18,100 per annum; and from 1920 to 1930 at the rate of 24,500 per annum. This represents an increase at the rate of 1.6 per cent per annum for 1899-1910, 1.8 per cent for 1910-20, and 2.2 per cent for 1920-30. The average per annum increase from 1930 to 1935 has been 30,800, or a 2 per cent increase. In the same period the total population increased to approximately 1,698,000, as of June 30, 1935.

Food has never been a checking factor on the population growth of Puerto Rico; if there is a check it is what Jefferson calls a luxury check, coming from those to whom hunger is unknown. The development of transportation, of irrigation, and of the use of fertilizers has increased the food supply much faster than population has increased.

San Juan owes its great growth, from 32,048 in 1900 to 115,000 in 1930, to its being the best port and the chief commercial city, as well as the capital, and to the existence of large numbers of landless who flock to it in search of a livelihood.

Map 3 shows population trends divided into four categories,⁵ as follows:

- A — Still growing
- B — Decline less than 25 per cent
- C — Decline 25 to 50 per cent
- D — Decline more than 50 per cent

The first category shows clearly that the greater portion of the northern half of the island is still growing and that, with few exceptions, all declines in this region have been less than 25 per cent. Under this category we can class: (1) practically all the northeast section (urbanization and tobacco); (2) practically all the southeast section (recent irrigation); and (3) practically all the northern half (cane, urbanization, tobacco, and citrus fruits). Under the second category, 0-25 per cent, there is no noticeable trend.

The third category, 25-50 per cent, is limited almost entirely to the western area, especially the northwestern, where the coffee

⁵ According to Professor S. D. Dodge's method outlined in "A Study of Population in Vermont and New Hampshire," *Pap. Mich. Acad. Sci., Arts and Letters*, 18 (1932): 131-132. 1933; and "Population Regions of the United States," *ibid.*, 21 (1935): 347. 1936.

region lies. This is due to the continuous decline in the exports of coffee caused by the loss of world markets and accelerated by the hurricane of 1928. Coffee exports in 1899 amounted to \$8,790,000; in 1930 they were only \$151,000.

The fourth category, over 50 per cent, except for one ward in the northern part of the island, is restricted to this coffee region and accentuates the magnitude of the decline. It also emphasizes the marked correlation which exists in Puerto Rico between population trends and the value of crops.

Map 2, the population-peak map, brings out in a clearer way some of the characteristics of the trend map. The white area (still growing) shows just how much greater is the area of growth than that of decline, and demonstrates more clearly just how great is the area that is still growing in the eastern region, especially on the large depressed drainage basin of the Loiza and the Rio Grande, the tobacco region. Again, the predominance of the peaks in 1899 and 1910 in the coffee region indicates when these barrios had their better days. The peaks which occurred previous to 1930 were distributed thus: 222 in mountain barrios, 46 in foothill barrios, and 30 in coastal barrios. They clearly point to a downward movement of population.

CONCLUSION

This study of population distribution, trends, and peaks, with the barrio as a basis, shows markedly the influence of the geographic factor on the density and the distribution of population, and the influence of the cultural and economic pattern on the trends of growth and on the year of peaks. A detailed study would show still more significant trends, by subdividing the first category (still growing) into different rates of growth, but in the present discussion it would put too much detail on one map.

UNIVERSITY OF MICHIGAN

A STUDY OF THE ORIGINAL VEGETATION OF WAYNE COUNTY, MICHIGAN *

W. BRUCE DICK

AN ORIGINAL-vegetation study of an area falls into the "natural-setting" category of geographical investigation. For such a study I have selected Wayne County, Michigan. Although aborigines were known to exist in this locality, their influence on the original vegetation is so slight that it is considered negligible. Thus the cultural aspect in reference to vegetation at this early period may be disregarded entirely.

The surveyors working under the General Land Office survey of 1785 witnessed their stakes by blazing two trees, and at the same time recorded in their field books the kind, the diameter, and the position of these trees in relation to the stakes. At the present time each county surveyor in the state has a copy of these field notes for his county.

On the basis of these notes the various kinds of trees were given their recorded position on a base map of the county in selected colors. Then the tree combinations were noted and the association boundaries drawn. Black and white symbols could have been used to represent the trees, but colors made it possible to recognize the associations more readily.

This method was utilized throughout the map (Map 4), except that in the northeastern part of the county a preëxisting survey, known as the "private claims" or the French Land Survey, required that the method be altered. In Cadillac's time the French were interested in water frontage mainly and ran their surveys at right angles to the shores of the rivers and the lakes. There are no witness trees recorded on the General Land Office Survey maps for the area shown by short dashed lines.

The private claims area thus required a different treatment in

* Collection of the data was made while the author was an Earhart Foundation Scholar at the University of Michigan in 1935.

reconstructing the original vegetation. Professor Veatch's system of using soil types as an aid in determining natural vegetation was considered, but the needed detailed soil map of Wayne County was found wanting.¹ The generalized soil map of the Detroit area pre-



MAP 4

pared by McCool and Grantham made it possible to reconstruct the vegetation types with less detail than appears in the rest of the vegetation map of the county.²

¹ Veatch, J. O., "Reconstruction of Forest Cover Based on Soil Maps," *The Quarterly Bulletin of the Agricultural Experiment Station, Michigan State College*, 10, No. 3: 116-126.

² McCool, M. M., and Grantham, G. M., "Soils of the Detroit Area," Michigan Agricultural College Experiment Station, Soils Section, *Special Bulletin No. 104*, November, 1920.

The classification of vegetation used in this study consists of four types: (1) oak, with a few hickories interspersed; (2) beech, with a few maples; (3) prairie; and (4) swamp.

In the southern part of the county is concentrated the oak-hickory association shown by the coarse stippling. Here also the better-drained brown sands are found. The generalized soil map indicates a continuation of the brown sands extending north into the center of the county and surrounding a small area of sandy loam. The sandy loam in this county correlates well with the beech-maple group shown by the vertical lines. However, the fact that the oak-hickory type is not so extensive as the brown sand might suggest is the result essentially of drainage conditions. The witness trees indicate here, instead of the oak-hickory type, a preponderance of swamp type, which reflects poorer drainage or the presence of stream bottoms. The island of oak-hickory in the northwest section seems to be situated on the edge of the brown sands and sandy loams, where the drainage is somewhat better.

In the northwest part of the county one finds a concentration of the beech-maple type. In regard to characteristic soils the sandy loams are associated with this vegetation type, which was also found to be representative of the higher and better-drained areas of this soil class. Hence the beech-maple combination is a little more restricted in area than the distribution of the sandy loams would suggest. The small patch of beech-maple shown in the southwest corner, along the county's west boundary, correlates well with a small protrusion of sandy loam from a larger area of the same soil class in the adjacent county.

The prairies constitute rather small scattered areas, shown by the fine stippling. In most cases the surveyors did not distinguish between the tall- and the short-grass prairies, but merely recorded that the stake was in "prairie." A few such recordings were found in the southwest section of the county and perhaps could be related to the "oak openings" that occur in oak associations elsewhere. Some areas of this type were noted along the southern shore of the Detroit River, and although the evidence is concealed by the private claims section, it is reasonable to assume that narrow strips of prairie existed here and there along the shore farther north, because of the wet lowland soils there. Additional studies of the soils may yield more definite information on this point.

The swamp type is represented by diagonal lining. In this group are found principally ash, sycamore, "poplar," "aspen," elm, willow, and ironwood.³ In several places the surveyors recorded that the stake was in "swamp," a designation similar to "prairies." Distribution of this type corresponds to that of much heavier soil classes, such as silt, clay, and *fine* sandy loams. These heavier soils and the swamp type occur especially in the middle-western portion of the county and in the northeast.

To get a somewhat better notion of the relationships of vegetation, soil, and surface diagrammatic cross sections were made from south to north in the western half of the county, where the information was not obscured by "private claims" (text Fig. 9).

The location map of the county shows in the lower right-hand corner the position of these graphs and cross sections. The numbers at the right of each pair of graphs correspond with the numbers at the foot of the location map. The oak, hickory, beech, and maple trees were counted within the boundaries of each surveyor's section from south to north along the line. Consideration of the swamp type was omitted because the illustration of the point that the oak-hickory were concentrated in the south and the beech-maple in the north was particularly desired. However, where the total height of the column is low, it can be understood that the swamp-type trees were numerous. In other words, had all the trees been considered, the height of the bars would be constant. Solid black represents the oak, and stippling indicates the hickory. Each of the three bar graphs shows a preponderance of the oak-hickory association in the south. A possible exception is perhaps noticeable in the second graph. This concentration of oak-hickory in the north corresponds to the island of oaks referred to earlier and may be due to local characteristics of the soil and drainage, which the generalized soil map does not reveal.

The graphs also appear to support the generalization that the beech-maple type dominates in the northwest part of the county. Although it is not so obvious as in the case of the oak-hickory, yet there is a concentration of the diagonal and the vertical lining representing the beech and the maples respectively.

In turning our attention to the surface cross sections below the

³ Species of trees are not indicated in the field notes. The terms "poplar" and "aspen" may have been loosely used, as they commonly are today.

bar graphs it should be pointed out that the vertical scale is greatly exaggerated. The United States topographical sheets furnished information concerning the surface, and the map mentioned earlier supplied the soil data.

The first pair of graphs show the oak-hickory on brown sand and extending over a little to the sandy loams, whereas the beech and

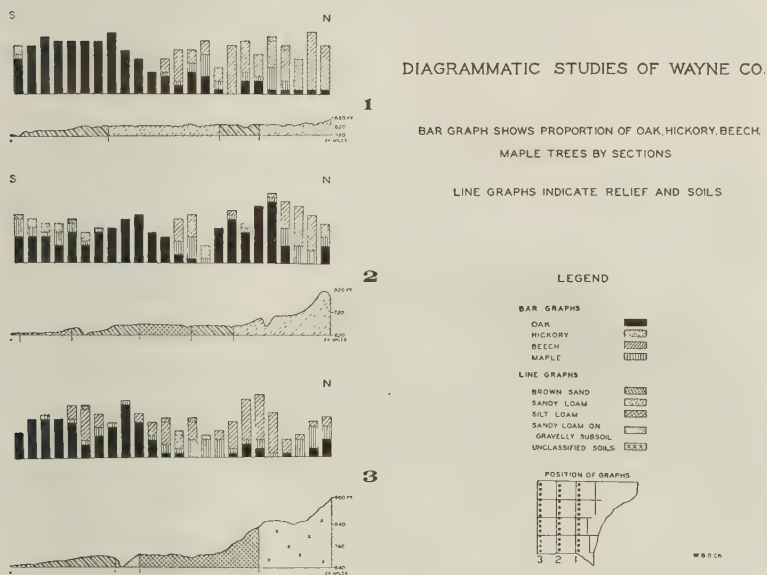


Fig. 9

maples extend the rest of the way northward. The small patch of brown sand in the north in the sandy loam area seems to have no particularly important limiting qualities.

In the second pair of graphs one notices a little more variety in surface and soil. One of the interesting features here is the presence of maple on the patches of heavier silt loams in the south, but the absence of beech. The detached body of oaks shown in the north section of the bar graph is not clearly accounted for on the basis of the cross section below. However, more detailed knowledge of the soils might provide the needed explanation.

The bottom pair of graphs show relations essentially similar to those below. In the south there are a few beech trees worth noticing which appear on the protrusion of sandy loam already referred to. The line of cross section is tangent to the boundary of this soil class and, consequently, the soil does not show on the graph. Vegetation, however, not always being restricted so sharply as soil, spreads over the boundary a little, and this accounts for the presence of the beech in the left part of the bar graph. The increase in relief of this cross section is due to the crossing of the northwest corner of the county by the edge of a morainic belt. The McCool and Grantham map is concerned with the old glacial lake soils, so that this small portion of the northwest corner was not classified. The drop in the height of the columns reflects the presence of the swamp association. There are two areas of particularly poor drainage and heavier soils which support the swamp type: one in the middle of the cross-hatched area representing silt loam, and the other at the foot of the morainic belt.

It has been pointed out that the field notes of the General Land Office survey afford a basis on which to reconstruct natural vegetation. Attention has been called to one difficulty in this method, but the occurrence of private claims did not interfere seriously with the use of the field notes, for their area is relatively small. Where detailed soil surveys exist, it is well also to reconstruct the vegetation in the manner Professor Veatch suggests and then to check the results of each method by the other.

Work of this kind has already been done in southwestern Michigan.⁴ In the future may there be more, for if geography aims at a complete description and interpretation of the earth's surface and the regional method of study is a vehicle to this end, then a small investigation such as this may be regarded as a portion of a much larger regional undertaking.

The writer is grateful to Professor S. D. Dodge for criticism and advice generously offered during the preparation of this paper.

UNIVERSITY OF MICHIGAN

⁴ Kenoyer, Leslie A., "Ecological Notes on Kalamazoo County, Michigan, Based on the Original Land Survey," *Pap. Mich. Acad. Sci., Arts and Letters*, 11 (1929): 211-217. 1930; and "Forest Distribution in Southwestern Michigan as Interpreted from the Original Land Survey (1826-32)," *ibid.*, 19 (1933): 107-111. 1934.

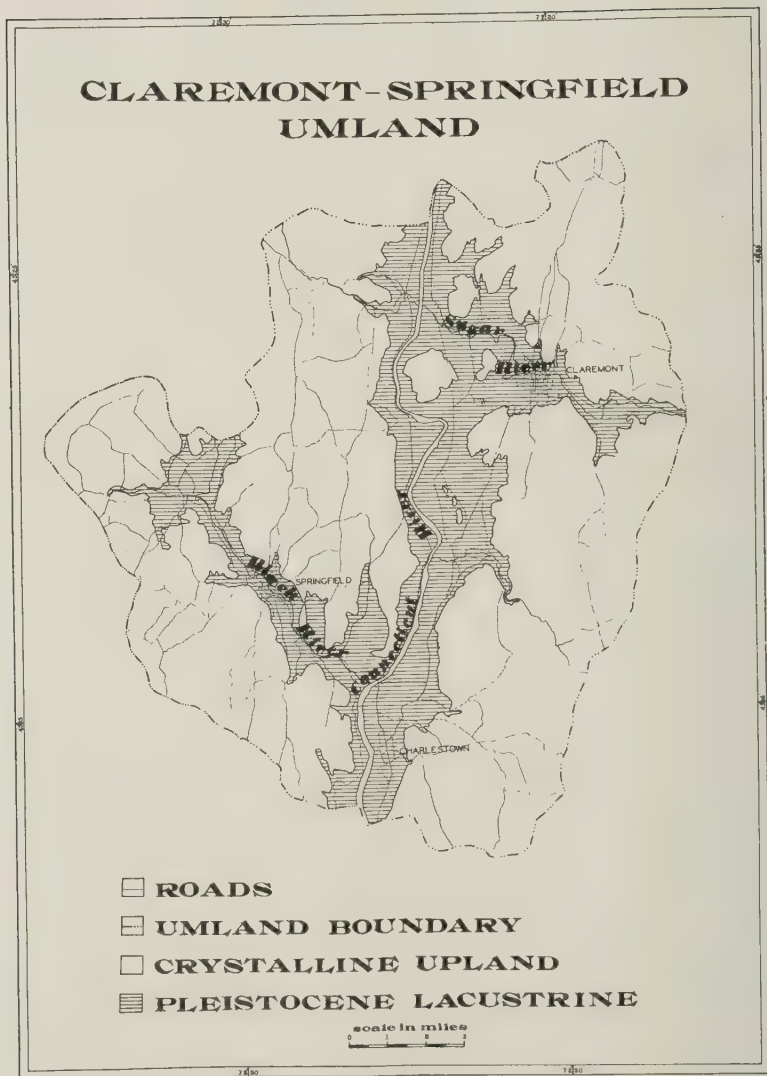
THE CHOROLOGY OF THE CLAREMONT- SPRINGFIELD REGION IN THE UPPER CONNECTICUT VALLEY IN NEW HAMPSHIRE AND VERMONT

STANLEY D. DODGE

MUCH of the writing of geography treats regions as static, as *being*, whereas it is the *becoming* which is important. What processes have shaped regions, what processes are continuing the elusive transformations, and what are the trends for the future (barring alterations in the basic data) — these are the questions which excite the field geographer. The following paragraphs are designed to illustrate the *becoming* of a small region on the upper Connecticut River and two of its tributaries, one in New Hampshire, and one in Vermont.

DELINEATION OF THE REGION

The area under discussion (Map 5) will be called for convenience "the Claremont-Springfield region," a name taken from the two small manufacturing towns which dominate it, Claremont up the Sugar River in New Hampshire and Springfield on the Black River in Vermont. The names of human agglomerations are often used as regional names, because they are conspicuous features of the local landscape, but in this case they actually designate a man-made area, one delineated by the trade of the two principal towns. In the processes of the occupancy of the Connecticut Valley in New Hampshire and in Vermont a certain tract of land has become the umland of Claremont, and another has become the umland of Springfield. These two umlands are practically indistinguishable along their mutual boundary, for the Claremont umland laps over the Connecticut River into Vermont, and it has been convenient, therefore, to consider them a single human region with two economic foci.



MAP 5

NUCLEAR SITES

The boundaries of umlands are established by people living and working in an area and, by some kind of decision, coming to trade habitually at a certain center. The center itself, like the boundary, is not static, but mobile, and this movement is a part of the becoming of the area. The boundaries of the Claremont-Springfield umland were made by people occupying the Upper Connecticut Valley in the eighteenth century, who linked themselves to Claremont on the east of the river and to Springfield on the west. In the case of Claremont the economic development at the original center has been intensified on the original site; in the case of Springfield, the original site has been abandoned, and a new site several miles away has become the economic focus of its umland. The site occupied by a nucleus of people starting a sequence of occupance in an area may be called the "nuclear site."

SITE OF CLAREMONT

On the Sugar River tributary of the Connecticut in the west-central part of Sullivan County, New Hampshire, there is a large area of level, flood-plain, meadow land. It has developed above a temporary base level occasioned by the river's here crossing the prominent western edge of the New Hampshire plateau before falling to the level of the Connecticut Valley. On the north and the south sides of the Sugar River flood plain, and thirty feet above it, terraces occur (Map 5). On the southern of these terraces the nuclear village of Claremont was planted in 1762. From this center the population region comprising the umland of the town has grown by pushing back the frontiers till they met those of adjacent population regions, Lebanon on the north and Bellows Falls on the south, Newport on the east and Ludlow, Vermont, on the west.

SITE OF SPRINGFIELD

The original settlement at Springfield was developed by colonies coming from farther south in the Connecticut Valley.¹ Before the

¹ From Northampton, Massachusetts. The colonies near by settled at Weathersfield, from Wethersfield, Connecticut; at Hartford, from Hartford, Connecticut; and at Windsor, from the town of the same name in Connecticut. These four Connecticut and Massachusetts towns were early offshoots of the main area of settlement about Boston.

settlement, the Upper Connecticut Valley was practically a wilderness, but it had at least been explored, for in 1760 General Amherst had constructed a road from opposite Old Number Four² across the hills and mountains of Vermont to Crown Point on Lake Champlain. This was built primarily for military purposes, but its location became important in connection with the founding of Springfield on its nuclear site.

The Crown Point Road

At the confluence of the Black River the Connecticut is less than 300 feet above sea level. Rising sharply above the Connecticut, the eastern edge of the Vermont Plateau presents a steep face toward the river, the cliff rising 600 feet in Skitchewaugh Mountain,³ a mile and a half above the confluence, although it rises less up and down the main river. Through the highland indicated by this escarpment the Black River flows in a gorge more than four hundred feet deep. At the date of the building of the military road the Black River gorge was filled with a tangle of swamp which made going difficult.⁴ To avoid this, General Amherst had the road built up a steep and narrow ravine at the south end of Skitchewaugh Mountain, to attain the relatively easy going of the surface of the plateau.

Once on the plateau, the Crown Point Road, still traceable in lanes and byways, strikes northwest to the slope of a broad ridge at Cross Roads 938. This is the site of Eureka,⁵ the original village from which Springfield sprang. Here on the old road a tavern was built (1772) to accommodate wayfarers. All that remains of the village that grew up near the tavern is a yard of ancient graves surrounded by a metal fence.

The second settlement was at Sartwell's Hill, and the third at Parker Hill, on the border between the present townships of Springfield and Rockingham. Shortly afterward a settlement was made at the place significantly called Hardscrabble Corner.

² Charlestown, New Hampshire, settled in 1737.

³ This and other details may be seen on the Claremont, N. H.-Vt. Sheet of the United States Geological Survey.

⁴ Hubbard, C. Horace, and Dartt, Justus, *History of the Town of Springfield, Vermont, with a Genealogical Record* (Boston, 1895); Baker, Mary Eva, "The Old Crown Point Road: Its Place in History," *Magazine of History*, 10: 269-274. 1909; 11: 22-26, 99-104. 1910.

⁵ Still locally so called on signposts.

Springfield

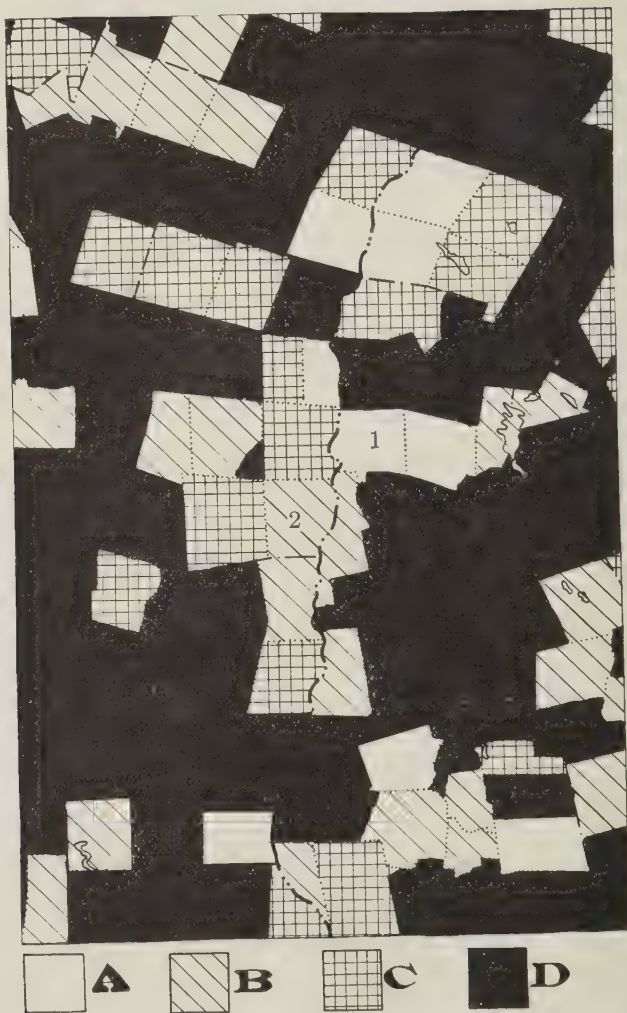
The site of Springfield itself, originally known as Lockwood's Falls, was the swamp on the north side of Black River. Just upstream from the center of present-day Springfield a ledge of resistant rock underlies the river, forming the first of a series of falls and cascades over which the river flows on its way through the gorge to join the Connecticut. Above the ledge, meadows and terraces of gravel occur, as at Claremont (Map 5). Downstream from the ledge the terraces are swampy, but adjacent to water power. It was this fact that occasioned the establishment of Springfield in the swampy section of the gorge. The first step in the establishment⁶ was the location of a sawmill at one of the falls in 1774. This became an economic focus secondary to that at Eureka on the hillside to the northeast and to the other hill settlements. From time to time other mills were established on the convenient water power, a grist-mill and a sawmill,⁷ and the significance of the swampy terrace above the tumbling Black River was enhanced. In this way a second economic focus became fixed relatively permanently in the Springfield area; the original Eureka settlement began to assume the aspect that it has today; and as the boundaries of the Springfield umland enlarged they pressed against those of Claremont till the two areas fused in effect, and Springfield from the second economic center of its own umland became second in the larger complex, in which it shares dominance with the New Hampshire town.

GROWTH AND DECLINE IN THE REGION

The Claremont-Springfield region, defined in terms of population conditions, is revealed by the map showing growth and decline of population (Map 6) to be but a portion, one section as it were, of a larger region which has been able to maintain its population, in part at least, although it is surrounded on all sides by areas which have suffered marked decline. When townships have lost more than

⁶ Hubbard and Dartt, *op. cit.*

⁷ It has not been stressed frequently enough that the original settlers in New England, far from being the "chosen people of a chosen people," were, on the whole, ill equipped for the American adventure. They were not primarily farmers, but small townsmen, "mechanicks," etc. Is it little wonder, then, that manufacturing should have made an early appeal and have had an early development on the numerous streams of the New England upland?



MAP 6. Population growth and decline

1. Claremont
2. Springfield
- A. Still growing (1930)
- B. Decline less than 25 per cent
- C. Decline from 25 per cent to 50 per cent
- D. Decline more than 50 per cent

fifty per cent of the population which they had at a peak, the decline has been considered to be marked.⁸

Detailed studies in other parts of New England have shown that, even where the population of a township has been able to maintain itself in a growing state, it is actually only the "center" that is growing, whereas the peripheral portions have suffered loss.⁹ Field surveys made in the summers of 1933 and 1935 show that the same condition obtains in the Claremont-Springfield region. Consequently, if the larger area of maintained population of which the region here under discussion is a part has become separated from similar areas elsewhere in New England by tracts of land with marked decline in population, it is not surprising that the Claremont-Springfield region is found to be hedged about by its own periphery of decline. This is indicated in two ways, by abandoned land, or land in the process of abandonment, and by abandoned roads and houses. Abandoned land does not mean necessarily that population has declined; it may mean merely that a more intensive economy characterizes the land remaining in cultivation. Therefore the abandonment of roads and houses, particularly the former, has been taken as an index of the zone of decline surrounding the Claremont-Springfield umland. This, however, is a function of the use of roads in the area and requires separate treatment.

ROAD TURNINGS AND ROADS

The general aspects of umland analysis in terms of roads have been discussed in another connection;¹⁰ all that is needed here is a presentation of the results of the particular field investigations about Claremont and Springfield. These are shown on Map 5.

ROADS

Within the framework of the umland boundary Claremont, Springfield, and a number of smaller villages, serving locally within

⁸ Dodge, S. D., "A Study of Population in Vermont and New Hampshire," *Pap. Mich. Acad. Sci., Arts and Letters*, 18 (1932): 131-136. 1933.

⁹ Bennington, Vermont, for example, was still growing in population at the 1930 census, but its margins were certainly declining. For details see S. D. Dodge, "The Vermont Valley: a Chorographical Study," *Pap. Mich. Acad. Sci., Arts and Letters*, 16 (1931): 241-274. 1932.

¹⁰ Dodge, S. D., "Bureau and the Princeton Community," *Ann. Am. Assn. Geog.*, 22 (1932): 159-209.

the area, have become the dominant centers. To them the outlying portions are united by a network of roads, which, except for the main ones, thin out into abandonment as they approach the margins of the area.

Roads about Claremont

Main roads

Two main roads cross at Claremont. One is the north-south road along the Connecticut, which bears east to include the city of Claremont; the other is an east-west road along Sugar River. The main road from the south leaves the terrace of the Connecticut River at North Charlestown, mounting to a higher terrace between Calavant Hill and the main upland at Perry Hill. Calavant Hill is a portion of the upland of New Hampshire detached from it in pre-glacial times and now surrounded by Pleistocene lacustrine deposits. The lacustrine deposits here have been eroded by Hubbard Brook, and the main road follows up the broad valley thus formed to a low pass¹¹ which leads to the high terrace at Claremont. Continuing north from Claremont, the north south road crosses Sugar River above the falls and ascends a small ravine to a low pass by which it reaches Stevens Brook, to follow that to its head, where another low pass leads to Redwater Brook. Up a tributary to that stream the main road passes out of the area on its way to Lebanon.

The east-west road follows the north bank of Sugar River eastward from the Connecticut River till it crosses to the south side into Claremont. It leaves Claremont by the bridge used by the north-south road, but turns east immediately along the terrace of Sugar River till the north terrace pinches out two miles from Claremont, when the road rises to the lower slopes between the river and Green Mountain and so leaves the area for Newport.

Minor roads

Whereas the main roads are of concrete, the minor roads are generally of gravel. The outstanding fact which gives a basis for subdivision into secondary and tertiary categories is that the most used minor roads (Class II) may be improved for some distance from the central town, whereas tertiary roads are mostly of graded

¹¹ Probably a channel for the overflow of water from Sugar River when the glacier blocked the main outlet.

dirt, except where, in their least used portions, near the boundaries, they peter out and are wholly unimproved. Thus the road leaving Claremont on the southeast is of concrete through Puckershire as far as the Sullivan County Home, but is continued by graded gravel over the hill to Unity. The tertiary road over Straw Hill is almost impassable, but, within the limits of the Claremont umland, is of passable graded dirt between West Unity and the uppermost house on the north side of Straw Hill. The road from West Unity to Unity could not be traveled in the summer of 1935, because bridges were out of repair and the roadbed was wet and grown up to grass.

Roads about Springfield

Main roads

The main highway north on the west side of the Connecticut River is of concrete north of the Cheshire Toll Bridge, which forms a link on a through route from southern New England and New York to the White Mountains. South of Springfield the road on the west side of the Connecticut is of minor importance and consequently has not been kept in good condition.

From the Cheshire Toll Bridge a concrete road runs up the Black River through Springfield to North Springfield, where it divides and becomes graveled. One section continues northward to Perkinsville beyond the Springfield umland, while the other ascends Great Brook and passes beyond the area near Davidson Hill.

Minor roads

Minor roads in a great network converge on Springfield and North Springfield. The latter is tributary to the former and thus makes a minor nexus in the road pattern. The whole of the extinct township of Baltimore, from Old Shineracker to Hawk's Mountain, embraces a territory served by minor roads which lead toward North Springfield. Weathersfield Center (Pl. XXXVIII, Fig. 1) is no longer active in the economic life of the area, but it is connected with Springfield and with Claremont by secondary roads. A short cut from Springfield to Claremont, the most used connection between the two centers of the compound umland, runs by way of Spencer School and the long slab down the slope below Rattlesnake Hill to the main road along the Connecticut, two miles below the little village of Weathersfield Bow.

GEOGNOSTIC ASPECTS OF THE REGION

The Claremont-Springfield area is characterized by two main types of land surface. These underlie the whole geographical complex of the region, and their details, finding surface expression in varying qualities of regolith, slope, and ground water, are among the chief nonhuman factors in the complex. The character and the aspect of each of the types cannot be discussed apart from a consideration of the agents which have been responsible for their formation. Two have been at work here, the streams and the continental glacier; the streams created an original surface, which the glacier and the streams acting together have modified. It is the modification which gives the two land-surface types: (1) the upland areas affected chiefly by glacial erosion; and (2) the lowland areas along the principal streams, which have received their present characteristics largely as a result of fluvio-glacial (lacustrine) deposition (Pl. XXXVIII, Fig. 2).

UPLANDS

The uplands of the Claremont-Springfield area comprise a section of the New England "peneplain."¹² The crests of the hills, rising to a general level of 1,300 feet, give a horizon which is broken only by the great and small monadnocks. Of these, Mt. Ascutney is the chief. Lesser hills rising more than 200 feet above the 1,300-foot "surface" occur on the margins of the area and represent the surface of a higher "peneplain." Differences of elevation between points less than two miles apart reach as much as a thousand feet, giving boldness and precipitousness to the slopes, especially near streams. The general surface is mature, except for the glacial modification, but occasional youthful areas, bordering the major water courses, suggest the amount of modification by streams which has taken place. The mature surface was developed on a complex of gneisses and schists, with the result that differences in the texture of the rock, except where modified by glacial action or covered by glacial débris, present differences in the quality of slope and surface.

The men who make their living out of an area and who are the chief agents in the cultural transformations of it are not much in-

¹² The quotation marks suggest that the word "peneplain" is here used to designate the even crest plane of the hills, and not to imply origin, about which, indeed, relatively little is known.

terested in the character of the underlying rock in the area in which they dwell, unless it bears minerals of worth, nor is vegetation ordinarily affected by it. What is of importance in both connections is the regolith, the mantle of transported or residual material which covers the rocky base, for this bears the ground water, this forms the soil¹³ used directly for crop growth, or, modified by manifold agencies, gives rise to "soil" in a narrower sense, which shows, in the Claremont-Springfield area, a tendency toward podsolization.¹⁴

The agencies which have modeled the upland surface have produced a variety of soils, which differ among themselves chiefly in the sizes of particles forming the matrix from the coarse pebbles, stones, and boulders. Most of the land is stony, except for pockets of colluvial and fluvial collection. It is the latter that provide the principal basis for agriculture (Pl. XXXVIII, Fig. 3).

LOWLANDS

The lowlands formed by the lacustrine deposits in the valleys of the Connecticut River and its tributaries occur in a series of terraces (Map 6; Pl. XXXIX, Fig. 1). The level of the topmost of these terraces, which were formed first on the melting of the Pleistocene ice, is 600 feet. Below this lie levels at 400, 320, and 280 feet, the last being the present flood plain. Much of this fluvio-glacial material is gravelly and is laid down in bands (Pl. XXXIX, Fig. 2). The coarse material forms a xerophytic habitat (Pl. XXXIX, Fig. 3). Where fine material is interbedded with the coarse, as it is in some of the lower terraces, the available ground water is greater, and the agricultural value of the soil correspondingly increased.

SUMMARY OF GEOGNOSTIC CONDITIONS

The uplands and the lowlands of the Claremont-Springfield area were formed by fluvial and glacial action on a complex of crystalline

¹³ There is no soil report for Sullivan County, but one was published for Merrimack County, next east, in 1906. The soils found there are for the most part repeated in Sullivan County, however.

¹⁴ True podsolized soils were not found at low elevations in the area of study, but they occurred in many places near Lebanon, sixteen miles to the north. At higher elevations podsolized soils were found near Claremont; for example, on the upper slope of Mt. Ascutney (alt. 3,144 feet) they were found above an altitude of 2,800 feet, near which level the change from mesophytic hardwood to boreal forest takes place.

rocks, and molded in the present surface aspect, particularly by these agents working in Pleistocene times. The principal land-surface and geognostic areal distinction is that between upland and lowland (Map 6); between these two the 600-foot contour marks the boundary, for it was the upper limit of lacustrine glacial water.

VEGETATION

Topographical analysis of vegetation forms presents one of the great difficulties in adequate geographical studies, yet the vegetation cover of the land, because of its intimate relations with ground water, soils, slopes, etc., and because of its inherent growth and reproduction (renewal) characteristics, becomes one of the diagnostically most valuable indices of land "quality." Two things seem to be desirable in the topographical analysis of vegetation forms: (1) a statement of the place of the area under discussion in its relation to the world framework of phytogeography; and (2) a study of the ecological and developmental qualities of the local plant associations themselves.

PHYTOGEOGRAPHICAL RELATIONSHIPS

The Claremont-Springfield area lies near the boundary between the "Lake Forest" and "Deciduous Forest" regions of J. E. Weaver and F. E. Clements,¹⁵ and near the southern border of the region in which *Pinus divaricata* is dominant, according to E. N. Transeau.¹⁶

Local field investigations suggest that the actual vegetation conditions are these: Just north of the area, in the vicinity of Lebanon, New Hampshire, boreal forest characteristics begin to assert themselves. These are noticeable in the occurrence of "spruce swamps" and the general replacement of hardwoods by black spruce (*Picea mariana*) in wet areas (Pl. XL, Fig. 1). The Claremont-Springfield area would seem, therefore, to lie not far south of the southern border of the Boreal Forest Mesophytic Hardwood Forest ecotone.

The species which characterize this general region are given by Nichols,¹⁷ as follows: *Tsuga canadensis*, *Acer saccharum*, *Fagus grandi-*

¹⁵ *Plant Ecology* (New York, 1929).

¹⁶ "Forest Centers of Eastern United States," *Am. Nat.*, 39: 875-889. 1905.

¹⁷ "Hemlock-White Pine-Northern Hardwood Region of Eastern North America," *Ecology*, 16: 403-422. 1935.

folia, *Betula lutea*, *Pinus Strobus*, *Tilia glabra*, *Ulmus americana*, *Fraxinus americana*, *Quercus borealis*, *Prunus serotina*, *Picea rubra*, *Abies balsamea*, *Picea glauca*, *Acer rubrum*, and *Pinus resinosa*. Hemlock (*Tsuga*), white pine (*P. Strobus*), and the hardwoods (especially *Acer saccharum* and *Fagus grandifolia*) give the region its name. The Claremont-Springfield area, therefore, lies near the northern part of the region where these species characteristics obtain, and not far from the southern border of the area in which more northerly phytogeographical conditions are found, especially in wet lowlands.

ECOLOGY

Vegetation associations studied ecologically yield, from a topographical viewpoint, further information concerning these matters. On the well-established assumption that progressive development toward a climax is taking place within all societies of plants, it becomes possible for one to be more precise on the subject of the local characteristics of vegetation, taking into account not only the broad general climatic climax, postulated by the climatic conditions and by the phytogeographical position of the area, but also the local details of seres in various stages of development, as revealed by field work.

DRY AREAS

Wherever it is sandy, wherever bare rock protrudes from the mantle of glacial soil, ecologically dry conditions are found. In the former, the soil, though sandy, is deep; the old glacial lake alluvium lines the streams and occupies local depressions on the upland (Map 6). In the latter, new seres, in the embryonic stage, point a lesson in the general development toward the climax.

The dominant tree of the sandy areas is the white pine (*P. Strobus*). The banks of the Connecticut River, where formed by terraces and where they are uncleared, support an almost continuous growth of this tree. It is almost an index of terrace geognostic conditions. Where the land has been cleared for agriculture, the regeneration of the natural vegetation in various early stages may be studied, except where regrowth has been prevented by agencies connected with man. Just north of the Ascutney Bridge across the Connecticut River part of a high terrace (600 feet) has been cleared of its growth of white pine (Pl. XXXIX, Fig. 3), and in

the cleared part various transformations are taking place in the flora as a part of the struggle of the vegetation back to its pristine condition. The terrace here provides a xerophytic habitat in which, in the sun, but not far from the edge of the remainder of the grove of white pines, the ground mat of the new growth is to be found. *Lycopodium* and lichens (reindeer moss) dispute with the coarse grasses the possession of the area. On north-facing slopes, where the habitat is more moist because of the absence of sun, *Myrica asplenifolia* is a characteristic species. The cutting of the white pine has been too recent, apparently, for any young growth of these trees to become established.¹⁸ The grazing and trampling of cattle may also help in keeping down the growth of young trees.

On bare rock areas an exposed, west-facing knoll on the west side of Bible Hill may be taken as an example. Here the sequence of development in the sere was as follows: a crustose lichen, a foliose lichen, a moss, two kinds of reindeer moss (lichen), sorrel (*Rumex acetifolia*), a blueberry,¹⁹ birch (*Betula populifolia*). All species within the quarter acre examined were arranged in the order indicated; the crustose lichens were pioneers, but were being overspread by foliose lichens, while the latter were being submerged by the growth of moss. With the establishment of the moss and lichen mat, sorrel came in, and, with increasing size of the plants, the complex was being built up to the pioneer trees, the birches.²⁰ The bare rock is trending in its vegetation development toward the climatic climax of the upland, except so far as man-induced factors, such as burning and grazing, interrupt.

JUNIPER SUBCLIMAX

Four cross sections were taken of a pasture on the high terrace one mile east of road junction 353 on the main highway north from Ascutney Bridge to Trinity, which is opposite Windsor, Vermont. Juniper, with some white pine on the margins of the area examined, was the dominant vegetation (Pl. XL, Fig. 2). The principal grasses of the pasture were fescues, but various other plants were definitely getting the better of them. *Potentilla canadensis* was a frequent in-

¹⁸ Cf. Dodge, "The Vermont Valley," *loc. cit.*

¹⁹ The lateness of the season made it impossible to find flowers from which identification could be made, but the blueberry was either *Vaccinium Vitis-Idaea minus* or *V. vacillans*, probably the former.

²⁰ Mostly. One specimen of *P. Strobus*.

vader, growing on *Lycopodium* (Pl. XL, Fig. 3). Many parts of the area showed this combination excluding the grasses, or these two plants, combined with *Achillea Millefolium*, dominating the grasses. It was apparently the *Lycopodium* which was bringing about the destruction of the grass cover, with *Potentilla* and *Achillea* acting as invaders on the club moss. *Juniperus communis* was spreading actively by rings, with dead "stolonoids" indicating the connection of the outer live ring with the inner live clump (Pl. XL, Fig. 2).

HUMAN ASPECTS

Human beings occupying the Claremont-Springfield area have so modified the land in adapting it to their use that they have erected a certain portion of its general area into a neatly delimited region having certain direct connections with the central towns. These direct connections and the neat delineation are expressed by the road turnings, which, as has been shown, indicate the development of a divide in traffic along many of the conspicuous ridges. The Claremont-Springfield region is not a physical region, but a man-made one. The limits are the limits of a human activity which finds its outlet in the marts of the world through one or the other of the focal towns.

This circumscribed area has now been occupied for a century and a half, and in that time the original vegetation has been greatly changed. The forests on the uplands do not now have the aspect that they had at the epoch of occupancy. Fields occupy uplands and lowlands and, now in part abandoned, are giving way to a new order of vegetation, the beginnings of the revival of the forest of birch, of beech, and of maple. This is the mesophytic Hardwood forest, which is becoming again adjusted to the climatic conditions after the interlude of cutting.

RURAL OCCUPANCE

Two aspects of rural occupancy require special consideration because of the large areal significance of their economy, lumbering and dairying. The former has given rise to various phases of the industry located in the periphery of the area; the latter expresses well the agricultural rural organization of the people and the consequences of it.

LUMBER WORKS

Throughout the length and breadth of the Claremont-Springfield area, on isolated higher and stonier hills, the vigorous second growth, which came up after the original destruction of the forest at the beginning of occupance, is now being attacked for firewood and for lumber, both primarily for local use. Firewood may be gathered anywhere in the area, but it is principally a phenomenon of the periphery. Plate XLI, Figure 1, shows wood piled beside the road that crosses Straw Hill near the southwestern margin of the area. This road is on a traffic divide, one of the criteria by which the limits of the area were determined.

Local sawmills are found (Pl. XLI, Fig. 2), which provide lumber. Logs are obtained at no great distance from the mill, and the lumber is sold at Claremont or at one of the wood-working mills at Springfield. The sites of abandoned sawmills, piles of lumber stored for curing, and the marks of old "tote" roads are further indications of this activity, and of its ephemeral local character (Pl. XLI, Fig. 3; Pl. XLII, Fig. 1).

DAIRY FARMING

Dairying is the principal form of farming. Hillside pastures, dairy barns (Pl. XXXVIII, Fig. 3), and milk-collecting stations are the geographic evidences of this. But, beyond these noticeable geographic aspects, the whole economy of dairying in relation to the land is revealed in its naked actuality by those vegetation determinations cited earlier. The use of the land for pasture, which is a principal concomitant of dairying, does not hinder much the natural regrowth of trees, so that groves of birch indicate the failure to maintain the pasture by plowing and resowing (Pl. XLIII). The other adjunct of dairying, in the economy of the region, is the hayfield. Here, again, vegetation analyses showed a host of noneconomic plants entering the domain of grass below the level reached by the mowing machine. Although the annual cutting of the less and less vigorous grass prevents effectively the regrowth of trees, it does not reach the zone of subtle change in the floristic character of the hayfield, so that the grasses are being pushed out gradually by the competition of weeds. Plowing and resowing should have been the remedy here.

These conditions are characteristic of the hilltop farms, where, indeed, the thin mantle of regolith made plowing unfeasible, and suggested, perhaps, as an alternative, the use of land year after year for hay or pasture, once the grasses had been sown. In the valley bottoms, on the other hand, the deeper regolith of fluvial and colluvial accumulation made plowing less difficult, apparently, and hence a better-balanced farming seemed possible (Pl. XXXIX, Fig. 1).

ORIGINAL POPULATION

Who were the people who were responsible for these activities? They were of English stock. In the eighteenth century they migrated up the Connecticut River from the then century-old settlements of Massachusetts and Connecticut.²¹ Like the original immigrants into New England, except as a hundred years of frontier life had modified imported habits, these people settled in the wilds of the Upper Connecticut without an ingrained habit of agricultural industry. The people of New England were never primarily, in spirit at least, a farming folk; they had a mechanical turn, developed in the towns of eastern England, enhanced a bit by the vicissitudes of frontier life, and later put to account in the development of industrial towns.²² It is little wonder, then, that a people so built should have soon left the hillside village of Springfield for the swamps at its base, there to build a factory town, or that the people of Claremont should have developed an industry *in situ*. That was their bent, and that they did.

The fields, cleared laboriously, were and are being quitted, not all at once, but one by one, and moss and briers are now to be seen where grass once grew. Where the road from Ascutney to Weatherfield Center crosses Goulden Ridge at a saddle a field still used for the harvest of hay illustrates the difficulties. The mowing machine leaves a stubble some two to two and one-half inches tall, and below the level thus indicated, in the zone relatively untouched by the activity of man, weeds are asserting themselves to the detriment of the economically essential grass. *Rumex* was found to be invading thickly, having become dominant in many large patches; parts of the strip traversed were found to be covered with *Convolvulus*, which was also locally dominant over the grasses. These low-lying plants

²¹ See footnote 1.

²² Cf. Barnes, V. F., *The Dominion of New England*, p. 137.

escape the mowing machine. There was also a moderate invasion of Solidago, which matures after the harvest of hay and sows itself plentifully. Complete abandonment brings complete regrowth, usually of birch on the upland (Pl. XLIII).

These vegetation determinations are an index of the failure of farming, and not of its impossibility. The Americans of English stock who planted the original, post-Amerind culture were not primarily agricultural; their bent was manufacturing. The development of industries in the area calls for examination, therefore.

CLAREMONT

The nuclear village of Claremont was established on a terrace above Sugar River. At this point the river starts its fall toward the lower level of the Connecticut, being held up by a ledge which forms the connection between hills to the north of Sugar River and their continuation to the south. Here, at an early date, factories were established (Pl. XLII, Fig. 2), and as a consequence the "center" of the town has moved north about a quarter of a mile to a portion of the terrace near the factories, with the result that the stores on the main square back up against the factory buildings along the river. The nexus of roads that forms the center of the town is related in part to the early routes of travel in the Claremont area, and these appear to have come to a focus at this point because of the local convenience of crossing the river. The manufacturing at Claremont is of textiles, and this lured workers from the older spinning and weaving towns of Massachusetts and Rhode Island. The wretched living quarters of these immigrants into the region have been built on newly laid out streets in the less desirable parts of the town, low against the river, in the edaphically dry gravel area below the falls. Here the street names suggest the origin of these newer people, Pawtucket and Woonsocket.

SPRINGFIELD

The nuclear site of Springfield has already been described in its swampy, industrial beginnings. It is an example of an industrial offshoot becoming commercial. The original industry, which utilized at the start local wood, sawing it for local needs, has been transformed to an industry with a wider market, which still utilizes such wood, in part, for the manufacture of snaths and boxes. A

local water power, as is the case in Claremont, is basic to the localization of the industry. In Springfield the industry came first, with commercial activities later; in Claremont trading preceded manufacturing.

CONCLUSION

The factories at both Claremont and Springfield have introduced into their joint area a new cultural tradition, that of southern and eastern European Americans. This is remaking the towns, and it is remaking the countryside. Many of the farms are now operated by recent immigrants or their descendants, and the phenomenon observed in the summer of 1935 may foretell the future of the whole area. On a hill north of Springfield a group of "peasant" women, eight in all, were seen reaping grain with sickles. If this indicates the future, as it does the toil that is apparently necessary for successful farming in the region, it may be that the sorrel and the briers, now conquering the hayfields and pastures, will be driven out again, and a more vigorous growth of grass and other crops introduced under the agency of capable men and women. The cultural transformation, in either case, will be profound. If the cleared land is further abandoned, the forest will reconquer almost inevitably; if there is a rebirth of agriculture, the growth of a new forest may be restricted. At present the whole region is declining economically, as indicated by the peripheral decline of population and by the floristic character of cleared land, and the alterations in the cultural landscape which are the result are also a part of the continuous processes of landscape change which it is the business of the geographer, at least in part, to detect and to describe.

UNIVERSITY OF MICHIGAN

PLATES XXXVIII-XLIII



FIG. 1. Remains of Weathersfield Corner



FIG. 2. Portion of terrace along Connecticut River



FIG. 3. Typical upland farmstead

PLATE XXXIX

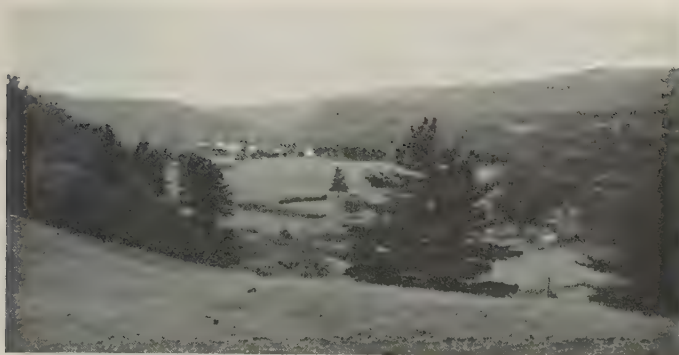


FIG. 1. Connecticut River lowland



FIG. 2. Banded glacial gravels



FIG. 3. White pine growth on terrace

PLATE XL



FIG. 1. First appearance of boreal forest



FIG. 2. Ground juniper



FIG. 3. Potentilla and Lycopodium

PLATE XLI



FIG. 1. Cord wood at traffic divide



FIG. 2. Sawmill. Note logs going in and boards coming out

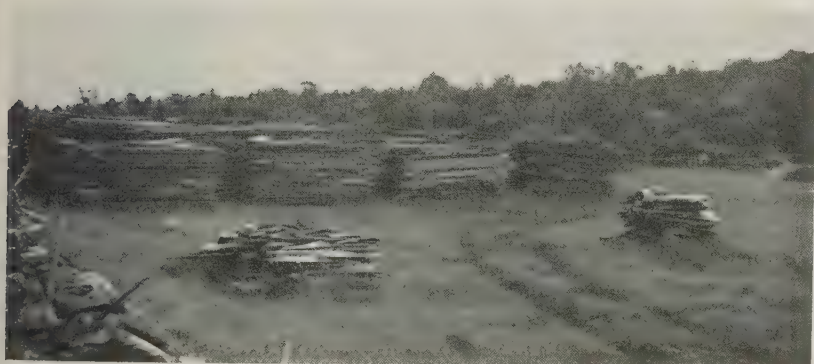


FIG. 3. Lumber piled to dry

PLATE XLII



FIG. 1. Abandoned sawmill site



FIG. 2. Factories at Claremont

PLATE XLIII



Field of birches

THE UMLAND OF HOWELL, LIVINGSTON COUNTY, MICHIGAN

STANLEY D. DODGE AND LEONARD S. WILSON

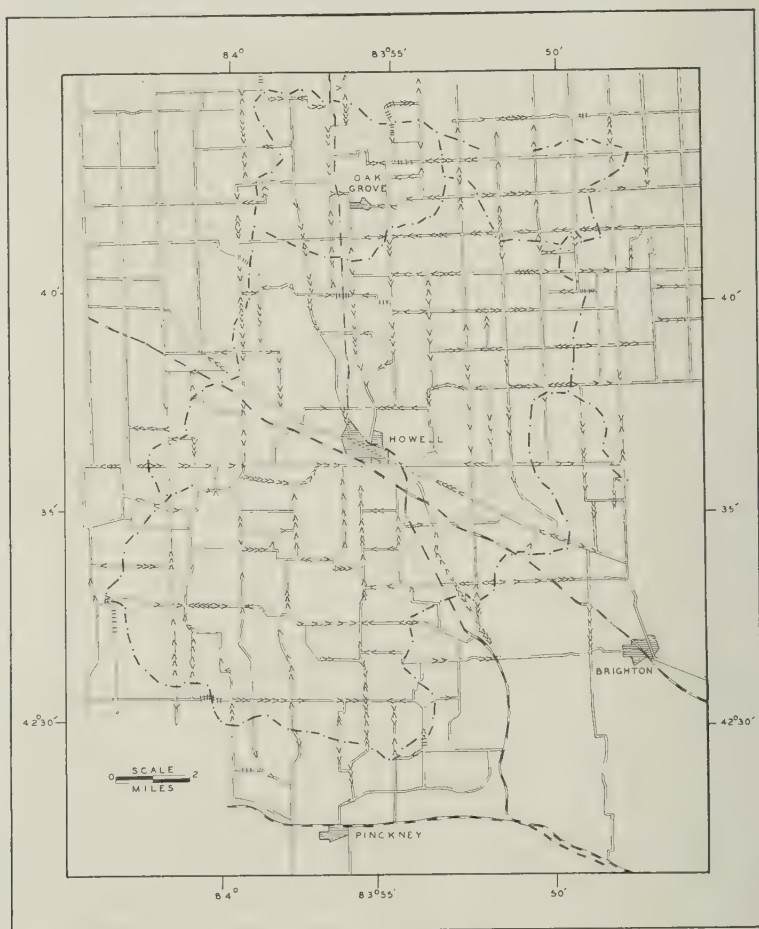
PURPOSE AND METHOD OF THE STUDY

THE field determination¹ of road turnings provides a convenient method of laying out the umland of any town which one may care to investigate. Essentially² the method used consists in mapping at each crossroad and at each entrance of a farmyard drive to a public road the direction in which the traffic normally turns. The turn is usually toward the town where trading is done habitually, and this makes it possible to delimit areas by the observance of recorded divergent turnings. Furthermore, a graded dirt road generally drops to a lower state of improvement in the section between divergent turnings, or, if indeed it once existed, it may have disappeared entirely in the growth of brush and saplings. This is called the "bad-road divide."

Heretofore road-turning determinations have been made only with reference to the umland of a single town, and it was desired to work out the mosaic of a number of contiguous umlands in order to see what phenomena were associated with the larger pattern. With headquarters at the University of Michigan the vicinity of Ann Arbor seemed a suitable laboratory, and accordingly a decision was reached to include the neighboring towns within the borders of Wayne, Washtenaw, Livingston, and Oakland counties. Since it has seemed easier to proceed out from a center to the limits of its

¹ Apparently determinations may be made in some cases from airplane photographs with the use of a sufficiently powerful glass. If they could be thus made in all cases, large areas might be blocked out in umlands quickly in the laboratory, without the time and expense, but also without the exhilaration, of field work.

² Theoretical and methodological discussion of road-turning analysis is provided in S. D. Dodge, "Bureau and the Princeton Community," *Ann. Assn. Am. Geog.*, 22: 159-209. 1932; see especially pp. 168-182.



MAP 7. Howell umland, showing road turnings

umland in all directions than to cross the umland boundaries, one center within the area to be worked was selected somewhat arbitrarily.³

³ Actually, the desire to escape as much as possible from the assumed influence of Detroit and to cooperate with others working on other problems in the Howell area prompted this selection.

pastures

The accompanying map (Map 7) shows the limits of the Howell unland, Livingston County. Along the roads from Howell one counts the turns at crossroads and houses, and the stream of traffic thus indicated is found to divide and subdivide as it lay out in roads of lower quality and less traffic use, on the margins of the area, especially on the south and the west, the expected bad-road divide is reached. On the north, minor villages alternate to confuse the pattern. These are Oak Grove and Parisville. Incomplete local coverage of traffic in the vicinity of Oak Grove, for instance, make it difficult to say whether that village belongs within or without the limits of the Howell unland, or, if the latter, whether it stands alone or as a part of the unland developed about Obovatoh, near the northern boundary of Livingston County, or Byron, north of that in Shiawassee County. In fact, one of the principal problems arising from the investigation of road turning is just this pattern of small villages. At present, the most trouble theory is that they occupy the interstices where two or more unlands come together, but it will take more complete analysis of the larger area represented by the four counties for which the study has been planned to begin to clear up this point.

Another problem is the perennial one of the quality of roads in relation to road turning and unland analysis. The quality of the road is certainly important in the case of bad-road divides, but the bad-road divide is not always present, certainly not along main traveled concrete roads, yet the unland boundary crosses them. It is hoped on the basis of an extension of the analysis here initiated to come to more definite conclusions on this point.

The relation of boundaries to natural and cultural features, to which they may be subsequent is another problem. In the Howell area only the southwestern part showed clear relations to a swamp and stream. The rest was vague.

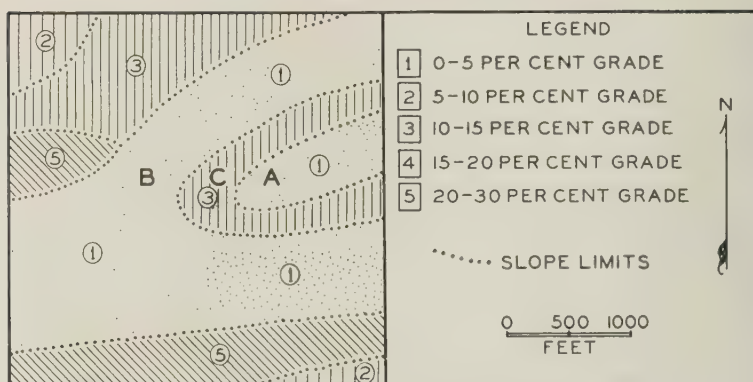
All in all, if road-turning analysis is to be useful in geographical and sociological investigations, it must be put on a more solid basis than it has been. Continued studies along the lines indicated above will, it is hoped, result eventually in a body of reliable data from which solid conclusions as to theory and methodology may be drawn.

THE SLOPE AND SLOPE-DIRECTION MAP

ROBERT M. GLENDINNING

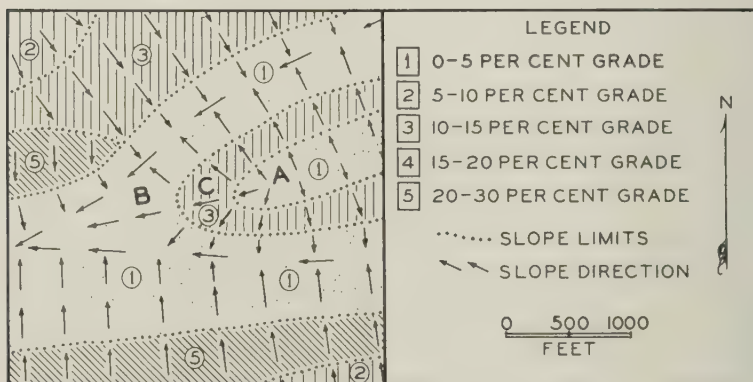
WHETHER one is interested in the purely academic or in the so-called practical aspects of geography, there is usually need for a method or a tool which will adequately reproduce the surface configuration of the portion of the earth being studied — a need for some device that will properly portray the essence of the “mold,” or the “lay,” of the land. There are many devices of this kind. They vary from such tools as the contour map and the physiographic diagram to aërial photographs examined stereoscopically. It is the purpose of this paper merely to indicate how a map made by combining a slope map and a slope-direction map may serve, at least in the larger scales, as one of such tools. In addition, it is proposed to indicate how such a *slope and slope-direction map* may be combined with other maps to “point up” the intricate relationships which exist between surface conditions and other landscape elements. This twofold objective may be best accomplished through the presentation of maps dealing with conditions of slope alone, and also with slope conditions related to certain other geographic items. An exemplary, rather than an exhaustive, treatment will be given.

Map 8 is an ordinary slope map of a sample area. It presents the area divided into its several slope classes or categories. The steepness of slope for each portion of the area is expressed in percentage of grade, that is, in terms of so many feet of vertical change for every hundred feet of horizontal distance. In the part of the area labeled *A* the slope ranges from 0 to 5 per cent grade. The same condition is found in the portion labeled *B*. In terms of the legend, both these portions have a number 1 slope. The part of the area labeled *C* has a slope of 10–15 per cent grade, or, in terms of the legend, a number 3 slope. A total of four slope classes is recognized in the entire area, the steepest of these being located in the southern and in the west-central portions, in which the slope is from 20 to 30 per cent grade. Map 8 thus presents the areal relationships of land facets according to their steepness. However, this map in no



MAP 8. Slope

way indicates the relative altitudinal positions of the several slope areas. For example, areas A and B have the same steepness; yet there is no indication as to which possesses the greater elevation. All that is known is that one is higher than the other, as indicated by the relatively steep area C which separates them. Area A is either a ridge top which drains across area C to area B, or a valley bottom which receives its drainage from areas B and C. It is in just this respect that the ordinary slope map fails to give an adequate picturization of the land surface.



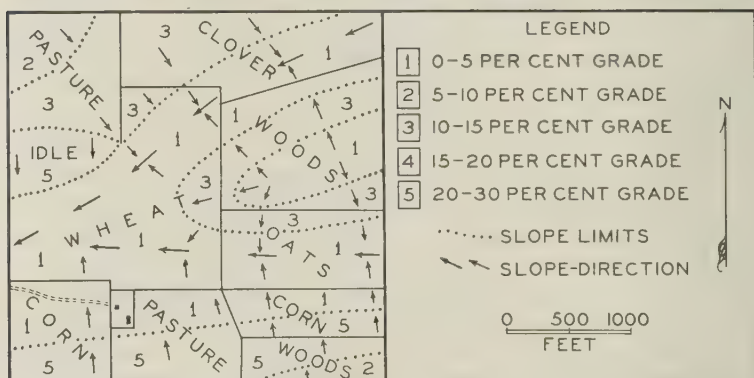
MAP 9. Slope and slope direction

Map 9 presents the same slope map as shown in Map 8, but to it have been added arrows which indicate the direction of slope. It thus constitutes a slope and slope-direction map. The addition of the arrows brings out the mold, or form, of the land and injects the item of relative altitude into the picture of the surface conditions. Now it is possible to see, by taking the example given above, that area *A* is a ridge top which slopes from a narrow crest to area *C* and that area *C*, in turn, slopes steeply to the bottom lands of area *B*. Furthermore, it can be seen that the lower parts of area *B* slope gently in a westerly direction; that area *B* collects the surface drainage of the entire area shown on the map; and that this surface drainage is concentrated in the western part of area *B* before draining off to the west. Map 9, by combining steepness of slope and direction of slope, as well as, incidentally, a picturization of the movement of surface drainage, succeeds in reproducing in cartographic form a reasonably adequate portrayal of the surface configuration of the area.

Maps 8 and 9 are concerned only with items pertaining to the "lay-of-the-land." As such they possess, in and of themselves, a certain value from the standpoint of geographic investigation. However, it is when the information which they convey is related to other landscape elements that they take on a more real and more useful significance. Just what relationships to such elements are to be shown will depend upon the nature of the investigation being conducted. The discussion which follows is based on arbitrarily selected examples.

In Map 10 the information of the first two maps has been combined with land use in order to indicate the relationships existing between surface configuration and the ways in which man is using the area. On this map the boundaries of the slope categories and the slope direction are indicated as before, except that fewer arrows are used to show slope direction; the limits of the several land uses are shown as heavy black lines; and the particular utilization of each use unit is printed within that unit. Inasmuch as a complete interpretation of Map 10 is unnecessary at this juncture, only portions of it will be discussed. To take examples: the cornfield in the southwestern corner of the map is shown to lie on two very different conditions of slope. The northern two thirds occupies a 0-5 per cent slope, while the southern third occupies a 20-30 per cent slope.

The arrows indicate that the southern part of the field slopes directly to the northern part and that surface drainage in the former portion must move rapidly, considering the use and the steepness of the land, into the lower, flatter section. In the northwestern part

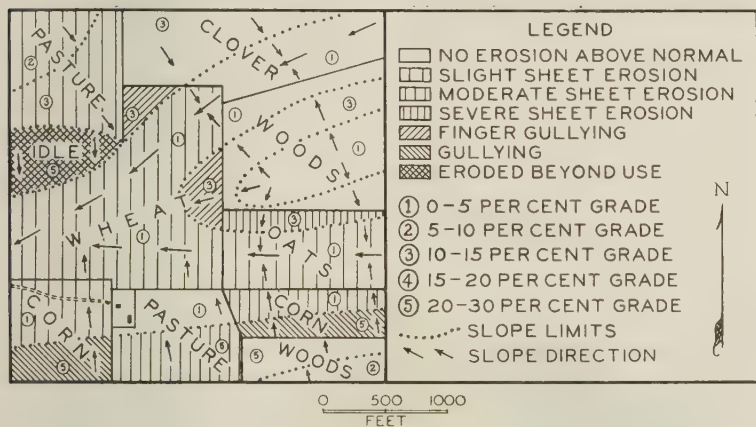


MAP 10. Slope, slope direction, and land use

of the map another land use, namely, pasture, likewise spreads across two degrees of slope steepness. The northwestern part of the pasture occupies a 5-10 per cent slope, while the southeastern portion lies on a 10-15 per cent slope. As indicated by the arrows, the slope of this field is toward the southeast. Other examples of the relationships of surface conditions to land use in this area would only indicate further that neither field pattern nor use of the land portrays any uniform adjustments to the surface configuration.

Map 11, again with slope and slope-direction information as a base, indicates the areal relationships of surface forms, land use, and, in addition, erosion conditions. The varying degrees of erosion above normal are indicated by different weights of vertical or oblique lining. Other items shown are expressed as in the preceding maps. If one takes the same examples as above, it will be noted that all the cornfield in the southwestern part of the area is eroding above normal. The lower and flatter portion is marked only by slight sheet erosion, but the higher and steep section is shown to be actively gullying. The pastured field in the northwestern portion of the area is marked throughout by slight sheet erosion, regardless of

steepness of slope. Additional illustrations may be taken. The clover field in the northeastern corner shows no erosion above normal, even though part of it lies on a 10–15 per cent slope. On the other hand, the cornfield near the southeastern corner of the area is moder-



MAP 11. Slope, slope direction, land use, and erosion

ately sheet-eroding on a 0–5 per cent slope and actively gullying on the portion of it which occupies a 20–30 per cent slope. Just to the south, the part of the woods likewise lying on a 20–30 per cent slope shows no erosion above normal. The area of idle land near the west-central part of the map occupies a similar 20–30 per cent slope; it is eroded beyond any possibility of cultivation. Ignoring at this time such factors as soil types, climatic conditions, erosion-control methods, and conditions of exposure, this map indicates that the kind of land use and the steepness of slope are important factors in erosion in this area. It will be noted that all the 20–30 per cent slopes that are not wooded are seriously eroded, whereas more gentle slopes are eroding, or not eroding, depending upon the nature of the land use. One of the major conclusions to be drawn from this map is that, in terms of erosion, there is considerable maladjustment between conditions of slope on the one hand and type of land use on the other.

The four maps just discussed will serve in a limited manner to illustrate the nature and the possibilities of the slope and slope-

direction map. Whether it is desired to describe surface conditions in and of themselves, or whether it is desired to show their relationship to other landscape elements as well, this type of map constitutes one sort of useful tool for those interested in describing and analyzing the surface of the earth.

LAND PLANNING AND HOUSING DIVISION
TENNESSEE VALLEY AUTHORITY

A MAP OF SETTLEMENT AGGLOMERATION AND DISSEMINATION IN JAPAN

ROBERT BURNETT HALL

THE morphological aspects of the various natural forms of the landscape are comparatively well known. Relatively exact methods of identification and classification have been developed, and quite accurate maps of world and regional distributions have been made.

There is a most obvious need for a similarly precise treatment of the cultural forms of the landscape. Human settlement is doubtless among the more critical of these. In recent years local studies have appeared in abundance, but little attempt has been made to standardize the method of approach.

The most elemental and basic geographical question concerning human settlement is whether or not an area is inhabited. Also of great geographical importance, in the inhabited portions of the earth, are the patterns of habitation distribution. In this study a logical beginning, and one which can be made for much of the world from available maps, is to determine where habitations occur in agglomerations and where they appear in disseminated pattern.

The accompanying map of Japan Proper (Map 12) is presented only as an example of a possible means of building up such data. It differentiates between inhabited and uninhabited areas, as well as between areas of agglomeration¹ and dissemination. A standardized method of procedure is suggested, though doubtless one which will be greatly altered with further experimentation. The methods and the criteria which follow are the result of sampling in several parts of the world for which detailed maps are available.

¹ The term "agglomerated" settlement has been used rather than "nucleated," which has sometimes been advocated, for the reason that the latter term implies a central thing about which the habitations have collected or are bound. Many compact settlements are simply gathered together without any center, functional or otherwise. The term "nucleated," however, might well be retained for those agglomerations, such as cathedral, market, and military towns, which are gathered about a center.

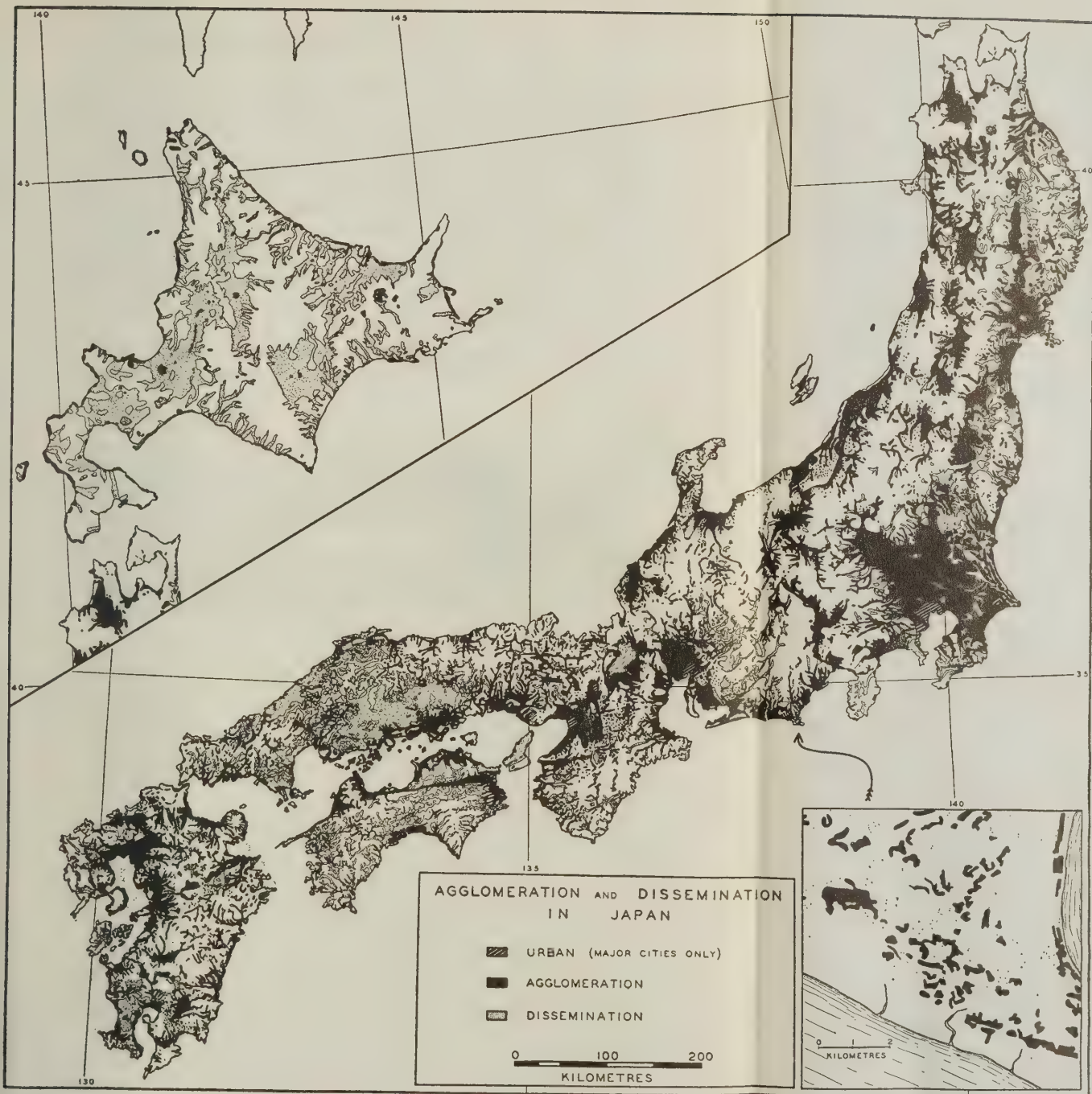
The map shows: (1) areas which are settled and those which are not settled;² (2) areas where agglomerated settlement prevails; (3) areas where a disseminated pattern of settlement is found; and (4) the major urban agglomerations (i.e. urban areas of one million or more inhabitants). The data given on the map were drawn from the Imperial Survey maps of Japan on the scale of 1:50,000, except for areas within fortified zones. For the latter places reference was made to the maps of 1:200,000. Many areas were checked in the field.

Each topographic sheet was analyzed by square kilometers, and the results were recorded on a gridded base of 1:2,000,000. This has proved to be a very satisfactory scale for recording such data and is one which can be conveniently secured for many parts of the world. The symbols were made to cover the sites of settlement and the agricultural area supporting it. The lower inset map, which was constructed on the exact scale of the topographic sheet, is shown to indicate the degree of generalization made.

An agglomeration is regarded as a grouping of six or more houses. Yards and kitchen gardens, but not fields, may separate the habitations within the agglomeration. The scale and the pattern differ from region to region with differences in agricultural systems, land values, etc. In a preliminary study two classes of agglomeration were mapped. "True agglomeration" encompassed those areas where 85 per cent or more of all habitations occur in groups as defined above. A second class included those areas where from 51 to 85 per cent so occur. This might be called "agglomeration tending toward dissemination." Two classes of dissemination were also recognized. "True dissemination" was charted for those areas in which less than 15 per cent of the habitations were in agglomerations, and "dissemination tending toward agglomeration" where more than 15 and less than 51 per cent so occur. However, since the two intermediate classes are generally absent in Japan and since no particularly positive features were brought out, only the broader classes were included on the final map. The fourfold classification emphasizes a number of pertinent conditions on experimental maps of Chosen, parts of India, and eastern United States.

Consistent with the general pattern of southeastern Asia, Japan

² Lone habitations in otherwise wide areas of unsettled land have been omitted, as have also known seasonal habitations.



MAP 12

is essentially a land of agglomerated settlement. Particularly is this true where paddy cultivation dominates and in coastal settlement where fishing is the main support. There are at least three important exceptions to agglomerated settlement, however: (1) The lowlands of Hokkaido have been populated since the Restoration, under a government plan compelling dissemination; (2) The granite mountains of southwest Honshu, inland from Hiroshima, offer scattered bits of agricultural land too small, in general, to support villages; (3) Such steeply inclined delta plains as those of the Oi Gawa and Hii Kawa are subject to frequent and violent flood, a situation which has led to the construction of individual elevated lots. There are also some minor exceptions to agglomeration which do not warrant discussion in so general a treatment.³

UNIVERSITY OF MICHIGAN

³ The cultural, historical, and natural reasons for agglomeration and dissemination of settlement in Japan have been partly described by the writer in "Some Rural Settlement Forms in Japan," *Geog. Rev.*, 20:93-123. 1931; "Settlement of the Hiinokawa Plain, Japan," *Papers Fifth Pan-Pacific Science Congress*, 1933:1359-1371; and "Cities, Villages and Houses of Japan," *Michigan Alumnus*, 40:138-139. 1934.

There is now also a vast volume of settlement literature in the Japanese language. Perhaps the chief works are the two books of Professor T. Watanuki, *Settlement Geography* (Tokyo, 1933) and *Settlement Geography of Japan* (Tokyo, 1935).

THE SURFACE CONFIGURATION OF SOUTH AMERICA

PRESTON E. JAMES

THE accompanying map of the surface configuration of South America (Map 13) recognizes the following categories of surface, each of which is given a somewhat more exact definition than is associated with its title in the lay vocabulary:

Plains. — Plains are areas of relatively slight local relief (less than 500 feet difference between the high and the low points of an area of roughly 25 square miles); they are low-lying with reference to surrounding areas, and are usually, but not in every case, low in altitude.¹

Plateaus. — Plateaus stand distinctly above neighboring areas, at least on one side, and have a considerable part of the surface at or near the summit level. Their local relief may or may not exceed 500 feet. A plateau, from the point of view of its physiographic background, may represent either a youthful land recently uplifted and with a considerable portion of its initial surface still preserved, or an area underlain by horizontal or nearly horizontal layers of stratified rock.

Hilly uplands. — Hilly uplands differ from plateaus in that a considerable part of the surface does not remain near the summit level. Their profiles, therefore, are rounded rather than flat-topped. Not uncommonly such areas are underlain by crystalline rocks forming a so-called crystalline oldland. The hilly upland differs from a plain in degree of local relief, having over 500 feet and less than 1,000 feet.

Low mountains. — Low mountains, it seems, should be distinguished from high mountains. These features are similar to hilly uplands in profile, but have a local relief of more than 1,000 feet and, generally, less than 3,000 feet.

High mountains. — High mountains are similar to the last two categories in that they possess rounded or peaked summits (as opposed to the flat-topped plateaus). A satisfactory working definition to separate them from low mountains calls for sufficient local relief to permit the development of marked vertical zoning of the vegetation cover.²

Intermont basins. — Within the mountain areas there are numerous intermont basins, more or less completely surrounded by higher land. Where such basins lie at a low altitude, perhaps representing only lowland extensions into the mountains, they are included with the plains; but at a higher altitude these basins are distinguished by a special symbol.

¹ For a résumé of these definitions see P. E. James, *An Outline of Geography* (Boston, 1935), p. 66.

² *Op. cit.*, p. 307.

In a number of instances these major divisions might well be subdivided. Because of the detailed differences in the landforms, crystalline areas should, if possible, be distinguished from areas with stratified rocks. Glaciated terrain is markedly different from non-glaciated terrain. In the low or the high mountain areas the intermont basins should be separated from the rougher surfaces. As the area to be treated becomes smaller, the number of such more detailed subdivisions becomes greater.

In any system of generalization the question of boundaries is apt to become troublesome. Should, for example, the foothills of a high mountain system — the marginal cuesta belt, let us say — be included with the mountains or indicated as a separate surface division? For two reasons the author has followed the practice of including such marginal areas with the larger division of which they form a part. In the first place, the data by which the marginal areas might be separated are not in every case available. But even if they were, the question of logic might be raised if an attempt is made to treat the boundary of a generalization too specifically. Therefore, foothills are included with the mountains unless they are essentially different; the dissected (and perhaps no longer flat-topped) edges of plateaus are included with the plateaus; and the low "rolling" surface on the margin of a hilly upland, even if it has a local relief of less than 500 feet, is included with the upland. The attempt is made to identify the critical changes in surface character and here to establish the boundaries rather than to apply any quantitative definition based on relief alone.

The original compilation of the new material on surface configuration was worked on a base with a scale of 1:6,000,000. In the reduction of the map presented here some of the detail has been lost.

GENERAL WORKS DEALING WITH SOUTH AMERICA AS A WHOLE OR ITS LARGER PARTS

- DENIS, P. *Amérique du Sud*. Vol. XV of *Géographie universelle*. Paris, 1927.
GERTH, H. *Geologie Südamerikas*. Berlin, 1932-35.
JONES, C. F. *South America*. New York, 1930.
MAULL, O., KÜHN, F., TROLL, K., UND KNOCHE, W. *Süd-Amerika. Handbuch der geographischen Wissenschaft*. Berlin, 1930.



MAP 13

SCHMIEDER, O. *Länderkunde Südamerikas*. Leipzig, 1932.

SHANAHAN, E. W. *South America*, Second Edition. New York, 1929.

SCHUCHERT, C. *Historical Geology of the Antillean-Caribbean Region*. New York, 1935.

MAPS

American Geographical Society, Millionth Maps.

Detailed topographic maps of parts of the following countries: Argentina, Brazil (São Paulo, Minas Geraes, Rio de Janeiro, and Federal District), Peru, Chile.

SMITH, GUY-HAROLD, *Physiographic Diagram of South America*. New York, 1934.

WORKS DEALING WITH SMALLER AREAS

Venezuela

CRIST, R. E. Along the Llanos-Andes Border in Zamora, Venezuela. *Geog. Rev.*, 22: 411-422. 1932.

HOLDRIDGE, D. Notes on an Exploratory Journey in Southeastern Venezuela. *Geog. Rev.*, 21: 373-378. 1931.

LIDDLE, R. A. *The Geology of Venezuela and Trinidad*. Fort Worth, 1928.

Colombia

BAUER, P. P. *N. W. Amazonien*. Brünn, 1919.

BRANDENBURG, L. *Der Rio Magdalena* Leipzig, 1923.

DE CIZANCOURT, H. Tectonic Structure of Northern Andes in Colombia and Venezuela. *Bull. Am. Assn. Petrol. Geol.*, 17: 211-228. 1933.

Ecuador

BENGTSON, N. A. Some Essential Features of the Geography of the Santa Elena Peninsula, Ecuador. *Ann. Assn. Am. Geog.*, 14: 150-158. 1924.

SHEPPARD, G. Notes on the Climate and Physiography of Southwestern Ecuador. *Geog. Rev.*, 20: 445-453. 1930.

SINCLAIR, J. H. In the Land of Cinnamon: A Journey in Eastern Ecuador. *Geog. Rev.*, 19: 201-217. 1929.

Peru

BOWMAN, I. *The Andes of Southern Peru*. New York, 1916.

STEINMANN, C. *Geologie von Peru*. Heidelberg, 1929.

Bolivia

MATHER, K. F. Front Ranges of the Andes between Santa Cruz (Bolivia) and Embarcación (Argentina). *Bull. Geol. Soc. Am.*, 33: 703-764. 1922.

OGILVIE, A. G. *Geography of the Central Andes*. *Am. Geog. Soc., Map of Hispanic America*, Publ. No. 1. New York, 1922.

SCHMIEDER, O. The East Bolivian Andes, South of the Rio Grande or Guapay, Univ. of Calif. Publ. in Geog., 2: 85-210. 1926.

TROLL, K. Die zentralen Anden . . . Zeitschr. der Gessell. für Erdk. zu Berlin, Sonderband zur Hundertjahrfeier der Gesell. (Berlin, 1928), pp. 92-118.

Chile

BOWMAN, I. Desert Trails of Atacama. Am. Geog. Soc., Spec. Publ. No. 5. New York, 1924.

MARTIN, C. Landeskunde von Chile. Hamburg, 1923.

STEFFEN, H. Westpatagonien: Die patagonischen Kordilleren und ihre Randgebiete. Berlin, 1919.

Argentina

BARCLAY, W. S. The Basin of the River Paraná. Geog. Journ., 79: 81-99, 186-200. 1932.

CALDENIUS, C. C. Las Glaciaciones Cuaternarias en la Patagonia y Tierra del Fuego. Geografiska Annaler, 14: 1-164. 1932.

KÜHN, F. Argentinien — Handbuch zur physischen Landeskunde. Breslau, 1927.

WILLIS, B. Northern Patagonia. New York, 1914.

Uruguay

WALTHER, K. Lineas fundamentales de la estructura geológica de la República O. del Uruguay. Rev. de l'Instituto N. de Agronomia, Ser. 2, No. 3. Montevideo, 1919.

— Über den gegenwärtigen Stand der geologischen Erforschung der Republik Uruguay. Zeitschr. deutsch. Wissensch. Verein zur Kultur und Landeskunde Argentiniens, 5: 373-399. 1919.

Paraguay

STOLTENBERG, I. Landschaftskundliche Gliederung von Paraguay. Mitt. geogr., Gesell. in Hamburg, 38: 69-130. 1927.

Brazil

BRANNER, J. C. Outlines of the Geology of Brazil to Accompany the Geologic Map of Brazil. Bull. Geol. Soc. Am., 30: 189-338. 1919.

JAMES, P. E. The Surface Configuration of Southeastern Brazil. Ann. Assn. Am. Geog., 23: 165-193. 1933.

MARBUT, C. F., AND MANIFOLD, C. B. The Topography of the Amazon Valley. Geog. Rev., 15: 617-642. 1925.

UNIVERSITY OF MICHIGAN

NOTES ON THE POPULATION OF FRANCE, WITH SPECIAL REFERENCE TO THE POPULATION OF THE AQUITAIN BASIN

HENRY MADISON KENDALL

THE population of France has maintained a small, but persistent, growth from 1801 to the present. This growth shows minor fluctuations, yet the 27 millions in 1801 had grown to 41 millions in 1931, and it is estimated that the 1935 number closely approaches 43 millions.¹ Despite this evidence for the whole country, there are certain sections that show decline, and by far the largest part is relatively stable. Decline in certain areas and relative stability in others have been attributed most frequently to the declining importance of agriculture, whereas continued growth has been accounted for solely on the basis of industrialization. That the decline of agriculture and the rise of industry are not the dominating items they are generally supposed to have been can be demonstrated by an examination of population change in numbers, occupational character, and density.

The graph of total population departs from a smooth growth curve in four major instances (Fig. 10). For the years 1811 and 1816 accurate census data are lacking. It can only be postulated that normal growth was continued. The interruption of census appears to have been brought about by difficulties of the Napoleonic régime. The second noticeable departure is a steepening of the curve in the years 1861 and 1866 and is accountable for by the addition to France of three Departments on the present Italian border. The exigencies of the Franco-Prussian War explain the third departure. The considerable drop in population numbers is the result of the loss by France

¹ The census statistics mentioned in this paper and used in the construction of the maps were obtained, in part, from the various volumes of *Annuaire statistique de la France* and, in part, from the various volumes of *Résultats statistiques du recensement de la population*.

of the Alsace-Lorraine area. The census of 1916 was omitted, but France shows a gain during the World War decade. This is the fourth departure from the expected curve. The increase may be explained nearly wholly by the fact that France recovered the area

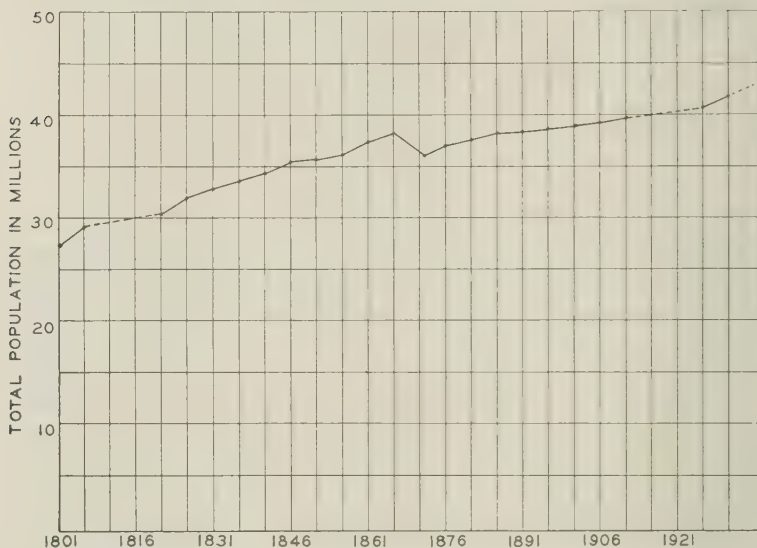
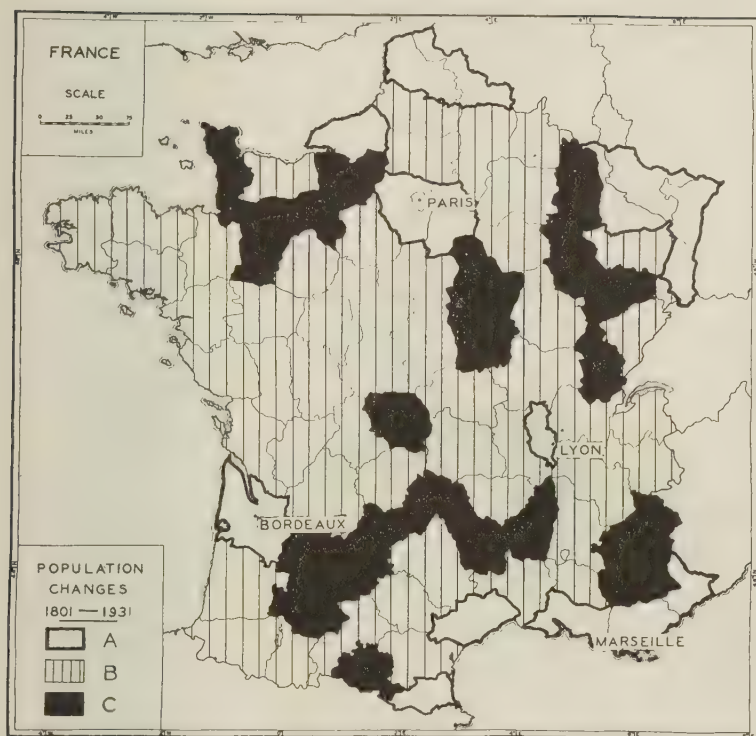


FIG. 10. Graph of population growth for France by five-year periods

lost during the Franco-Prussian War. Departures from a smooth curve may be explained mostly as war gains or losses.

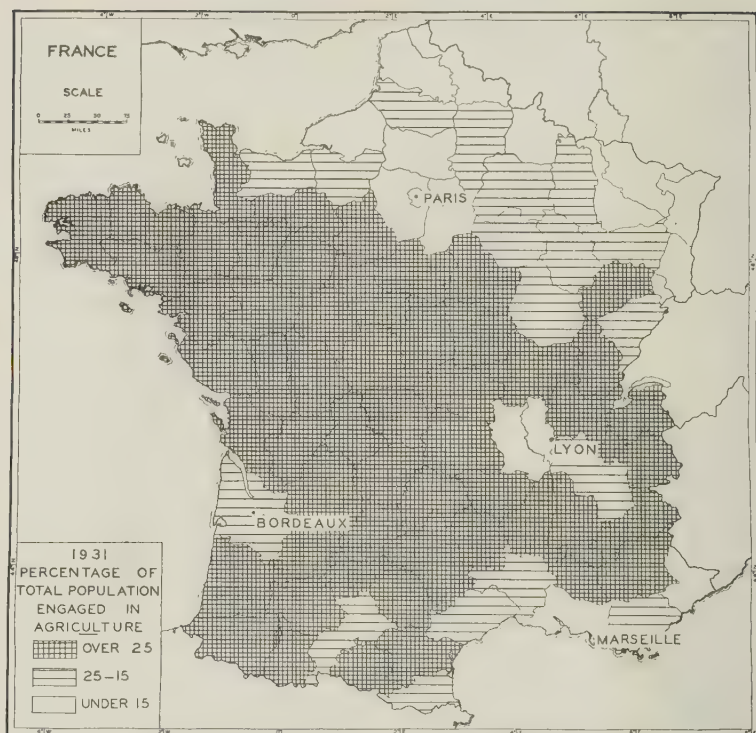
The continued growth in population numbers for the whole of France is not mirrored when the statistics of the 89 Departments are examined (Map 14). Three growth categories² may be recognized: (1) those Departments showing continued growth; (2) those that are essentially stable; and (3) those that have declined from 25 to 50 per cent from a peak number. Of the 89 Departments only 17 show continued growth, 51 are essentially stable, and 21 have definitely declined. Growth is limited to about one fifth of the country, whereas decline is the rule in nearly one quarter.

² For a discussion of this method of population study see S. D. Dodge, "A Study of Population in Vermont and New Hampshire," *Pap. Mich. Acad. Sci., Arts and Letters*, 18 (1932): 131-136. 1933.



MAP 14. A, continued growth; B, decline of from 0 to 25 per cent; C, decline of from 25 to 50 per cent

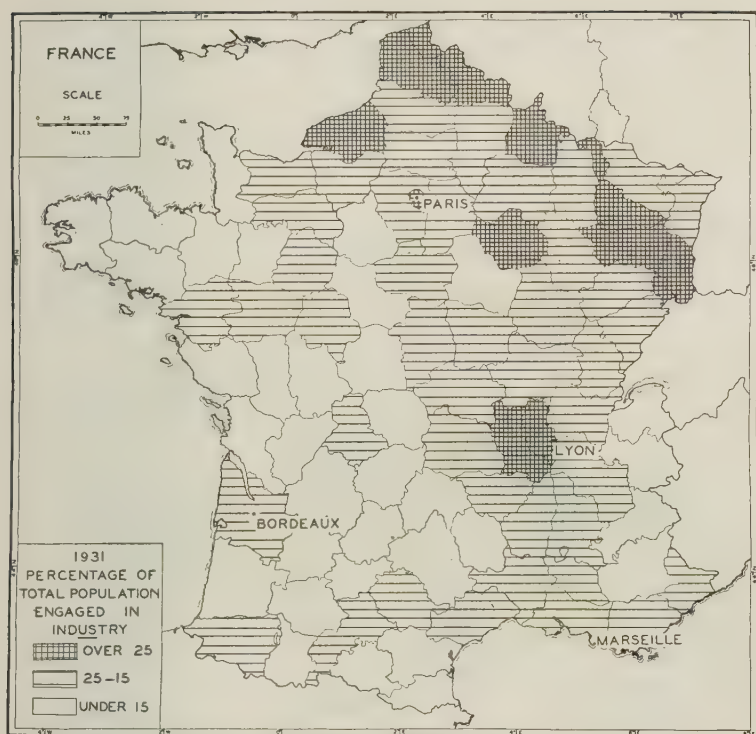
Since it is often stated that population decline is a rural phenomenon and that continued growth occurs as a result of industrialization, the facts of the occupational character of the population should afford a reliable check. For France as a whole the percentage of the total population engaged in agriculture is 19. If this figure is used as a mean, three categories may be established: (1) strongly agricultural where the percentage is 25 or more; (2) average agricultural where the percentage is between 25 and 15; and (3) nonagricultural where the percentage is less than 15. On this basis it can be seen (Map 15) that the few nonagricultural Departments are mostly concentrated in the northern part of the country.



MAP 15

Nineteen per cent of the total population are likewise engaged in industry, and, when one examines the same type of map for industry, the position appears nearly reversed (Map 16). Only 12 Departments are strongly industrial. They are mainly in the northern part of the country, as were the nonagricultural areas. If, however, individual Departments are considered, it will be noted that the strongly industrial areas are not always the nonagricultural ones, and, on the other hand, neither are the agricultural areas necessarily the nonindustrial ones.

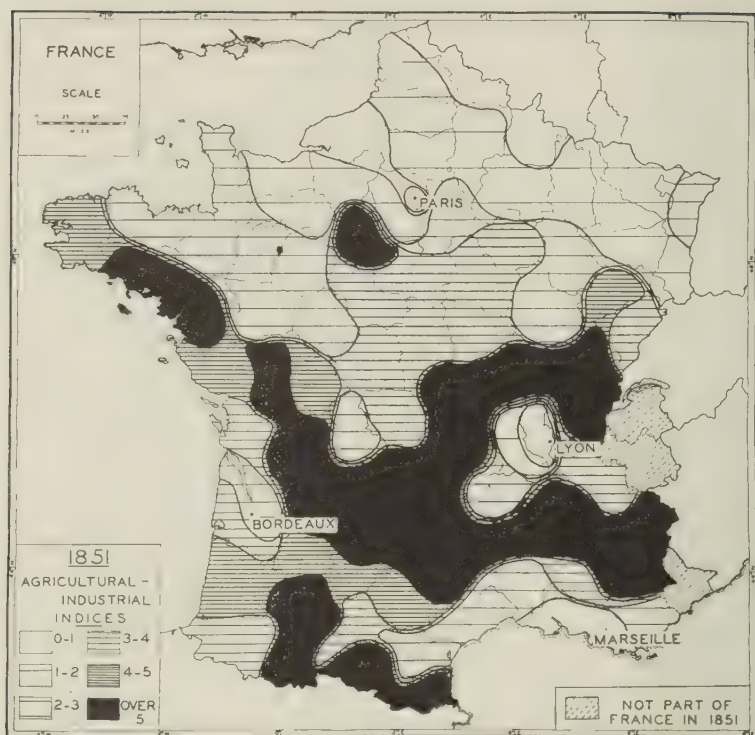
A more nearly true picture results from the construction of an isarithm map of agricultural-industrial indices. An index was determined for each Department by dividing the number of people in



MAP 16

agriculture by the number in industry. The smaller the index, the more strongly industrial is the area. Conversely, the larger the index, the more agricultural is the area. The indices change over a period of years and thereby indicate the changing relative importance of agriculture and industry.

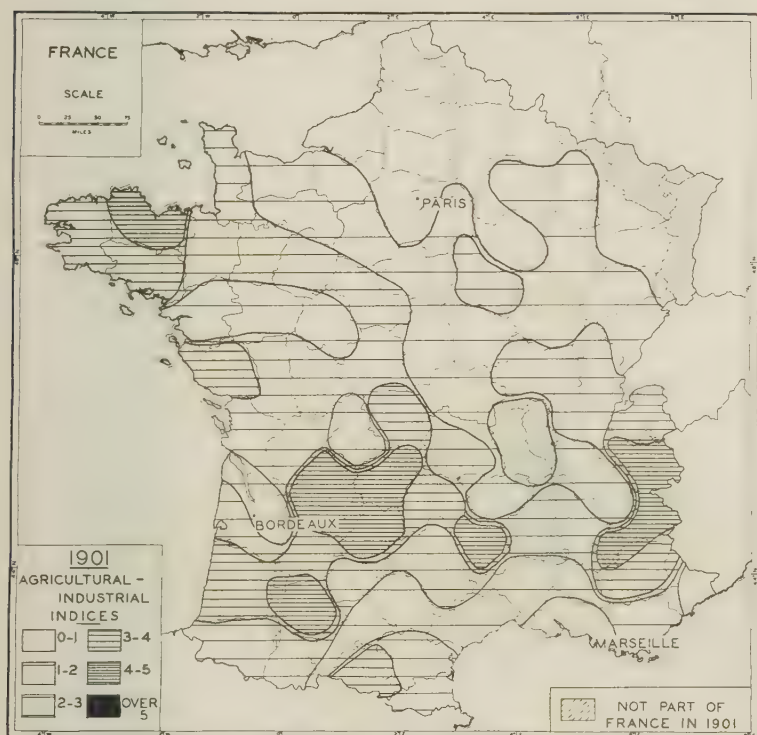
In 1851 (Map 17) only four small areas of France show indices of 1 or less — the area around Paris, around Marseille, around Lyon, and in the extreme northwest of the country. Throughout the central part of the country there is a large area in which agriculture is of dominant importance, where the index is over 5. In 1901 (Map 18) a marked decrease can be noted in the importance of agriculture. In no part of the country does the index reach 5. There is also an



MAP 17

increase in the area which is dominantly industrial. Marseille and Lyon remain as marked centers, but the area of the northwest has spread to join that of Paris and includes considerably more of the north of the country. One concludes that there was a relative decline in importance of agriculture and an increase in the importance of industry in the fifty-year period 1851-1901.

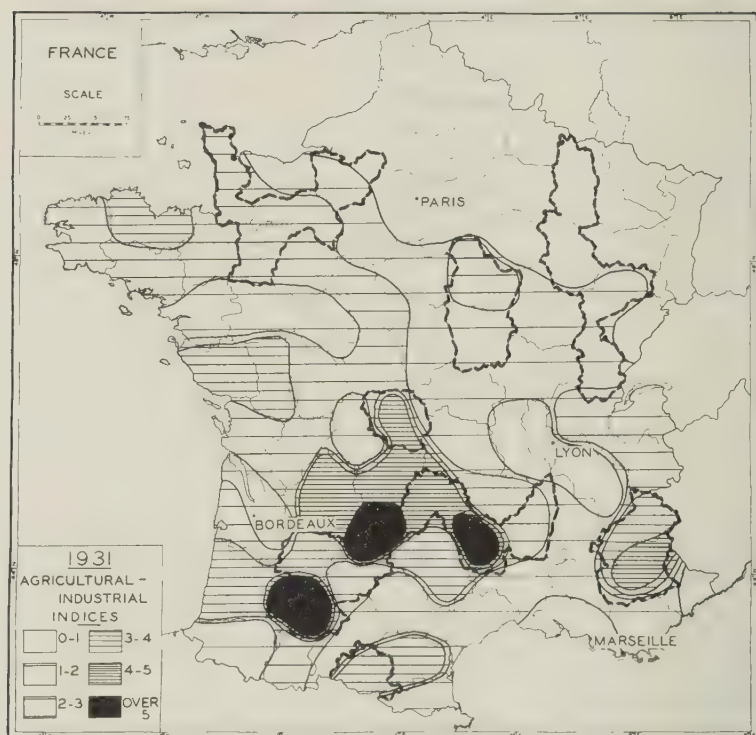
The map for 1931 (Map 19) indicates an increase in the area with an index of 1 or less, but the centers of expansion are the same as in former years. However, contrary to the usual statement, there is shown an increase in the relative importance of agriculture. Three areas in the south-central part of the country have indices of 5 or more, as indicated in black. When the outlines of the areas of de-



MAP 18

clining population are superimposed, it can be noted that, while some of the decline is in strongly agricultural sections, some is likewise in areas of mild rurality and some of the decline is actually in areas that are dominantly industrial.

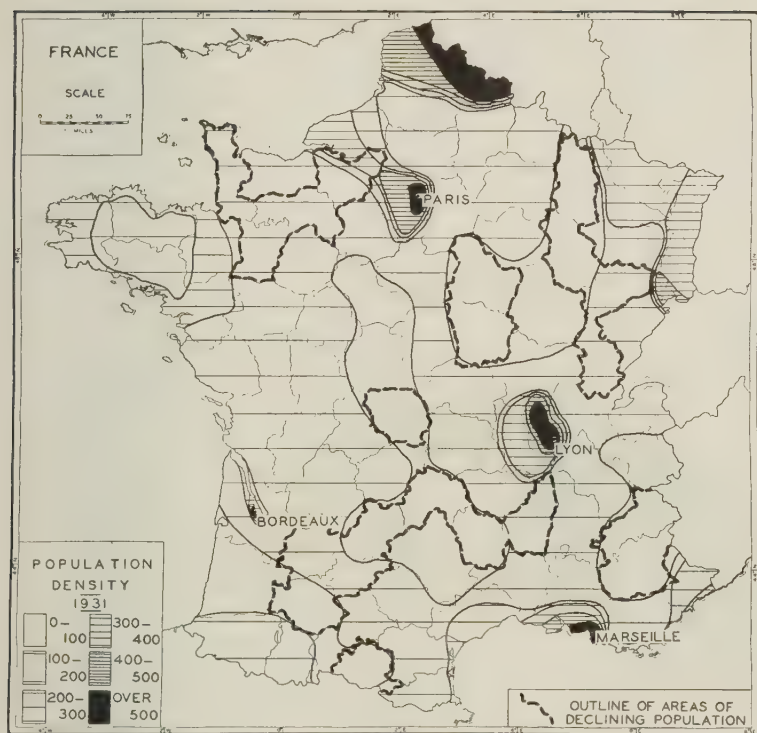
A map of gross population density for 1931 (Map 20) indicates five parts of France with over 500 persons per square mile. Four are centered about the main cities — Paris, Marseille, Lyon, and Bordeaux — and the fifth is in the industrial northwest. Much of France has a density below 100 persons per square mile. Decline is occurring in the sections of low density — mostly less than 100 persons per square mile. On the other hand, not all the areas of low density are declining in population numbers.



MAP 19. Dashed lines indicate outlines of areas where population has declined 25 to 50 per cent

On a coarse scale three facts are apparent: (1) while the population of France has shown continued slow growth, certain parts of the country have very definitely declined, and by far the largest part of the country has reached a relatively stable position; (2) the decline cannot be said to be the result of a declining relative importance of agriculture alone, nor can increase be accounted for solely by industrialization; and (3) while decline is confined to relatively sparsely populated sections, not all the thinly peopled parts of the country are showing decline.

Throughout an area as large as France there are numerous differences in the physical nature of the land. It is these differences

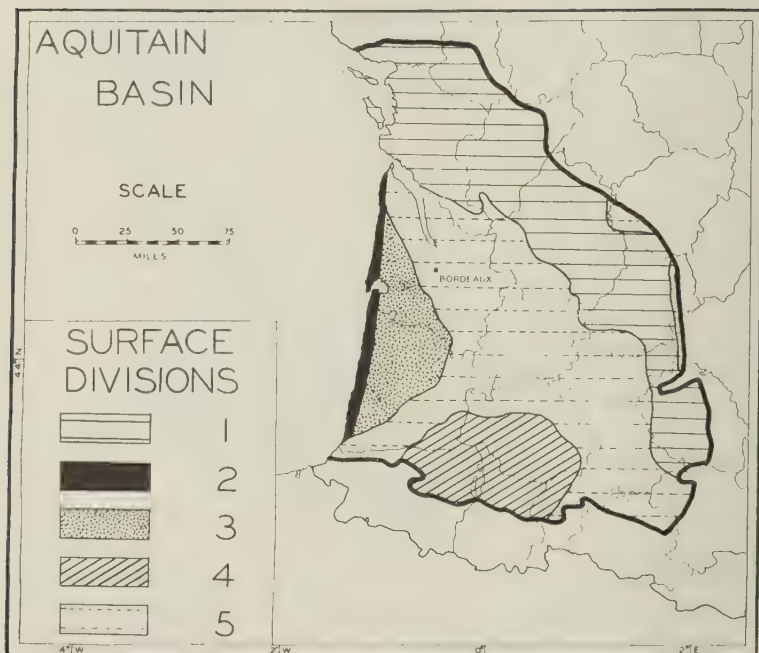


MAP 20

which have been frequently cited as the sole causes of the facts of population distribution and change.

One of the well-recognized physical regions of France is the Aquitan Basin, which is a sedimentary land fitting in between the old land of Brittany, the Massif Central, the Pyrenees, and the Bay of Biscay. Its surface consists of five major types of land, each of which owes its character not only to the manner and geologic time of deposition, but also to the way in which destructive forces have combined to dissect it (Map 21). Stretching along the northeastern fringe of the basin is a series of low-lying limestone plateaus which have been deeply incised by streams. Though there is considerable variety in this zone, the common characters are rather wide, flat-

floored valleys filled with recent alluvium and separated by flat-topped edaphically dry interfluvies which are mantled by only a thin veneer of lime-poor soils. The second type of surface is a narrow line of dunes which fringe the coast for all but a short stretch



MAP 21. 1, low-lying limestone plateaus; 2, sand-dune area; 3, coarse sands underlain by hardpan; 4, highly dissected fluvio-glacial detritus; 5, weakly dissected alluvial plain

in the south and as far north as the Gironde estuary. Just inland there is a triangular area of relatively recent marine deposit where the surface is cut by sharp, though not deep, youthful valleys. This is a region of coarse sands underlain by a very resistant hardpan. The fourth type of land consists of a semicircular area of detrital material reaching out from the lower Pyrenean slopes. It is differentiated from the main lowland because of the roughness of surface resulting from deep dissection by radially disposed streams.



MAP 22. Areas of declining population superimposed on surface divisions of the Aquitain basin

It is characterized by narrow youthful interfluvies and asymmetrical youthful valleys. The fifth surface type is one of slight relief. The materials are marine and fluvial alluviums and their elevation above base level is so slight as to have brought about their rapid dissection and reworking by the many streams which course over them. Of the five types of surface the last mentioned provides the best conditions for population growth both agriculturally and commercially.

When the map of population categories is compared with the map of surface divisions, it can be noted that the only Department showing continued increase is the one in which Bordeaux is located. Most of that Department is within the lowland, and the increase

is an expected one. The curious fact is the strip cutting directly across the surface divisions in which population is definitely declining (Map 22). Some of the area included within this strip is in the limestone plateau region, where decrease might be expected, and some of it is in the deeply dissected detrital zone stretching out from the Pyrenees, where it might also be expected. Most of it, however, is in the fertile lowland, and there it would not be expected if the physical conditions of the land are the determining factors of population distribution and change.

When the map of gross population distribution is compared with both the surface division and the population category maps it must be concluded that it is not a matter of extreme density that is bringing about the decline of the lowland. For all the lowland excepting that part near Bordeaux the density is well below the average for France as a whole. It cannot be said that there is indicated a drift of population toward the cities, for much of the population concentration about Bordeaux is related to the intensification of viticulture and not to the performance of urban functions within the city itself. It must be noted also that there has been a recent increase in the importance of agriculture throughout the Aquitaine Basin, so that population decline cannot be said to be synonymous with agricultural decline.

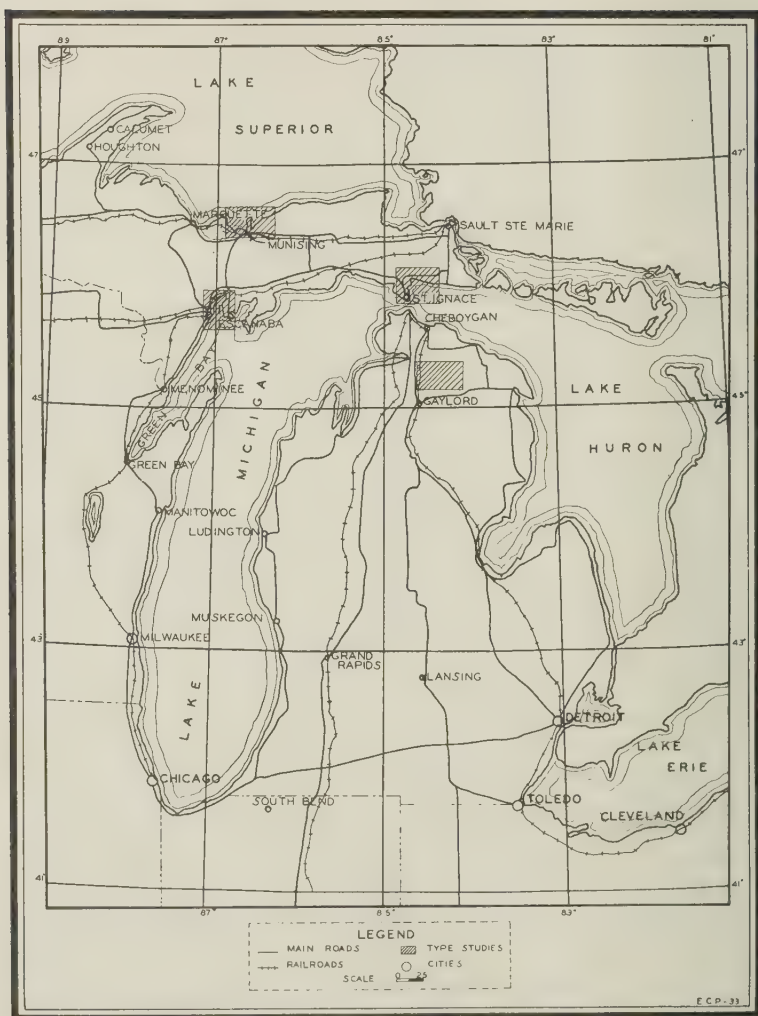
This study is on a coarse scale, and consequently it cannot hope to discover the full explanation of the situation as it exists either in France as a whole or in the well-recognized regions of the country separately. It is hoped, however, that it will serve to illustrate some of the major factors involved and at the same time to show the complexity of a problem which is so frequently passed over by sweeping generalizations. Population growth categories, population densities, the occupational character of the population, and the physical character of the land when considered alone fail to enlighten us; together they offer a somewhat blurred picture. There are many more factors which must be taken into account before a clear focus allows the picture to be sharply defined.

SOME TYPES OF RECREATIONAL LAND USE IN MICHIGAN

A SERIES OF TYPE STUDIES

EDWARD C. PROPHET

THE relatively extensive use of northern Michigan lands for recreational purposes is a recent development. It has provided this part of the state with an additional industry, expressing itself largely through increased employment. Unfortunately, up to the present time it has been exploitive rather than constructive, just as are most of the other major human activities of the area, such as lumbering, mining, trapping, and land booming. A movement is now under way to make it constructive and permanent rather than purely exploitive. The people of this area realize, or at least their leaders do, that they must find some source of employment which will continue indefinitely into the future and which does not take something away from the land. Accordingly, they are turning more and more to recreation as their last hope for such an industry. The forest has been cut and burned to such an extent that lumbering is no longer a dependable source of employment to a major portion of the population, as it has been in the past. With the decline of lumbering, farms which furnished supplies to the lumber camps have ceased to be profitable undertakings, and in some localities even the mines are beginning to fail. It is inevitable that the area will be abandoned unless some other source of employment is found. Fortunately, the automobile, which has become more and more important in our civilization during the last twenty years, and good roads, which the automobile has forced on most areas, have made this region readily accessible to about thirty million people. Map 23 shows the major lines of transportation serving the northern part of the Lower Peninsula and the eastern part of the Upper Peninsula. "The North Country," with its sparse population, its lakes and streams, its wild lands, its game, its beautiful scenery, and its cooler climate has proved very attractive to the city dweller who lives just south of it



MAP 23. The transportation routes shown are the through ones carrying most of the traffic. Other, less-used, routes exist, but have been left off the map to avoid confusion resulting from too much detail. The shaded areas correspond to the areas included on the detailed maps shown later

and is likely to become an even more popular vacation land as people find that they have more time for recreation owing to the leisure that is being forced on them by the machine age in which they live.

The map shows four type studies which have been chosen to illustrate various recreational uses of land or resources and also to show the ways in which certain resources function in developing and maintaining this industry.

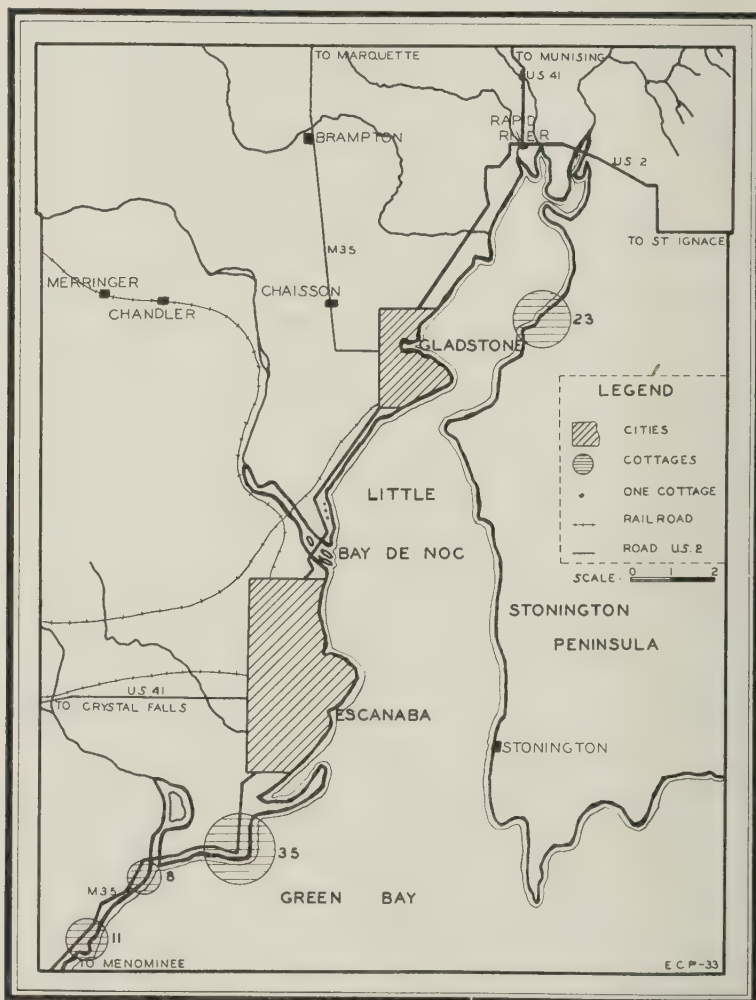
Motorists, to the number of eight or ten thousand, annually make a tour around Lake Michigan. Incidentally this is a very conservative estimate, made from relatively reliable data obtained by the State Highway Department of Michigan. These cars have an average of three or four passengers each.

ESCANABA

The route takes tourists through Escanaba, located at the north end of Green Bay (Map 24). It serves purely as an overnight stopping place for the majority of them. The hinterland is not inviting, since it was lumbered at an early date and is now very badly burned over. At the best it is covered with a poor stand of brush and is a monotonous plains area. No effort has been made to provide cottages on the bay shore for visitors or to develop boating or swimming facilities in the adjoining bodies of water. The cottages east of Gladstone and south of Escanaba, shown on the map, are owned and maintained by local residents of Escanaba for their own use and pleasure and usually are not available for visitors during the summer months. The city has a very large number of tourist lodginghouses and restaurants, as well as fair hotel accommodations. No effort has been made to keep or delay visitors in this area by providing anything that will interest them, so that their stops are of short duration. Escanaba is merely a stopping point on the route to somewhere else and, accordingly, it behooves the resident to pluck the plumes of the bird of passage (as the tourist really is) while he is en route. Fortunately, discretion has been used to the extent that the traffic has not been unduly discouraged.

MUNISING

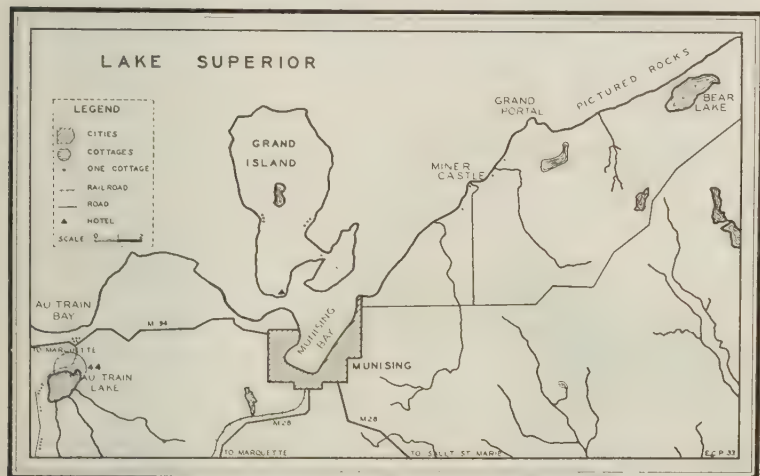
Munising is also a tourist town, but it has a definite resource to attract the tourist (Map 25). The Pictured Rocks, which are reached



MAP 24. Escanaba, Delta County

Note the absence of cottages on the Stonington Peninsula except across from Gladstone, and the concentration of cottages along Green Bay south of Escanaba. The latter site is more accessible to Escanaba, which has resulted in its development

from this point, serve as a magnet which draws visitors to this area. For many people they are an objective, not merely an incident of a trip. Munising has a very beautiful site. It is located on a magnificent, almost land-locked bay and is backed on the land side by heavily



MAP 25. Munising and vicinity, Alger County

wooded, deeply dissected cliffs. Many people call it the Naples of America. Lodginghouses are numerous, and the spirit of a resort town is not lacking here as it is in Escanaba. The wooded slopes lying back of the town are likely some day to be covered with great summer estates, but much must be done before that will be a reality. One thing that Munising needs and needs badly is a good fire. The chief calamity from such a fire would be the survival of some buildings. If it were possible to get rid of the shacks that disfigure the shore line, then man could rebuild in a way which would not detract from the beauty that nature has here provided. The main attraction is, of course, the Pictured Rocks, the cliffs which border Lake Superior to the east of the town. These cliffs extend for about twenty-five miles, and visitors are shown them from boats. The cliffs are composed of a resistant limestone, which rises sheer from the water's edge. They vary in height from seventy-five to three hundred feet and have been cut by the waves into many fantastic forms. Stacks,

caves, arches, and waterfalls, where streams drop from their gorges over the cliffs into Lake Superior, provide a variety of scenery which is very pleasing and interesting to the visitor. Except at Miner's Castle it is almost impossible to see the Pictured Rocks from the land side. The operating of boats to take visitors to see the rocks has proved a very profitable business and employs many of the residents.

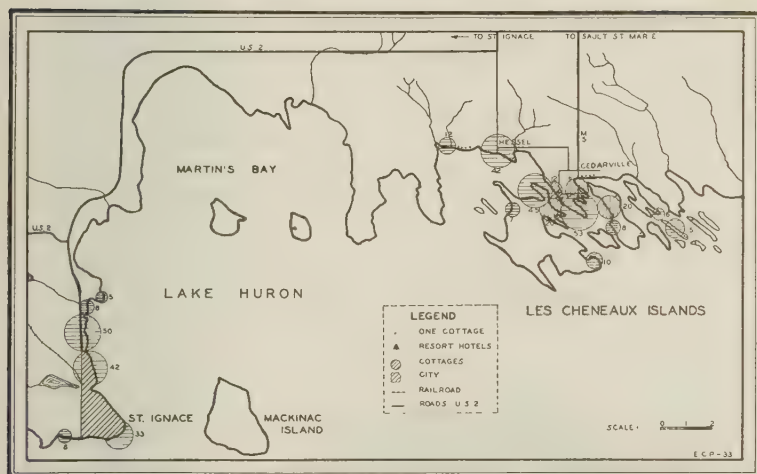
Grand Island, which shuts off Munising Bay from Lake Superior, is a privately owned recreation area. The Cleveland Cliffs Mining and Timber Company, one of the largest employers of labor in the Upper Peninsula, owns the island and maintains it as a summer resort for their office men and for officials of the company. A large resort hotel, the Williams Hotel, is operated by the company for the use of its employees. Hunting is prohibited, and the virgin timber has never been disturbed, making it a wilderness park in the true sense of the word. It may be that this island will be opened up to the public in the near future, since the company has suffered in the depression, as have other concerns, and would like to derive some revenue from its investment on the island.

To the west of Munising, at Au Train Lake, is a very promising summer-resort development. There are now fifty-nine cottages, most of which are rented to summer visitors. With the exception of about a dozen, all have been built during the last five years and the colony is expanding rapidly. The majority are owned by local people and rented to transients, but a few were built by individuals who return to this area every year and want to own their own places. An effort is being made to increase this kind of resorter.

LES CHENEAUX ISLANDS AND ST. IGNACE

The third type study discusses two sharply contrasting developments in the southeastern part of the Upper Peninsula. These two areas are Les Cheneaux Islands and St. Ignace (Map 26).

St. Ignace is the eastern entrance to the Upper Peninsula. Its function is much like that of Escanaba, being a stopping point for tourists on their way to other localities. During the last eight years a real effort has been made to provide better facilities to take care of resorters, with the result that about one hundred new cottages have been built. Some of these are very fine log cabins, but most of them are used to house overnight visitors. St. Ignace has had a bad reputation for overcharging the tourist, and the practice still persists, in



MAP 26. St. Ignace and Les Cheneaux Islands, Mackinac County

spite of the efforts of some citizens to live it down. The psychology is: "Get what you can from the tourist. You may never see him again." The old exploitation idea is still present in a vicious form.

At St. Ignace itself there is little of interest for the visitor, but within easy driving distance there are several features that could be used to entertain him. The land in the immediate vicinity is low and swampy or else composed of limestone outcrops, and the timber has been cut or burned, giving it a desolate, uninviting appearance. Actually, it is depressing to the beholder, so that it does not encourage residence for any length of time. The map shows the relative location of the cottages and the general site of the town. The majority of people who go to the trouble of crossing the "Straits" from the south do not linger long at St. Ignace. Thus its primary function is that of a terminal at the east end of the Upper Peninsula and an entrance to the Peninsula from the rest of the state.

About twenty miles to the northeast lie Les Cheneaux Islands. These islands are the site of one of the finest summer resorts in the state. An outcrop of relatively hard dolomitic limestone, dipping gently to the south and having a strike running from northwest to southeast, extends obliquely into Lake Huron. The receding glacial waters cut many channels through this outcrop, and the present lake

level is such that the channels are flooded and the outcrop exists as a series of islands. A very thin layer of soil is found here, and the islands are covered with birch trees, from which they have obtained their name, Les Cheneaux. Deep but narrow channels between the wooded islands, which have many bays and coves, provide unexcelled waters for fishing and boating. The natural beauty of the region is very striking, especially when compared to the areas near it, and it attracted resorters at an early date. For a long time visitors came only by boat from Mackinac Island or St. Ignace, which were reached by the large lake passenger boats. For forty or fifty years Les Cheneaux have been a summering place of the socially prominent from the lower lake region. Now that they can be reached overland by road they serve a larger number of people, but they have not lost their atmosphere of refinement and quiet. The islands are still frequented by the exclusive class, and it is almost impossible for newcomers to purchase either summer estates or cottages in the older established clubs. Newcomers have had to content themselves with sites for their summer homes on the mainland or on outlying portions of the islands. The site of this development is as ideal as any in all Michigan for a summer colony and was one of the first chosen for development.

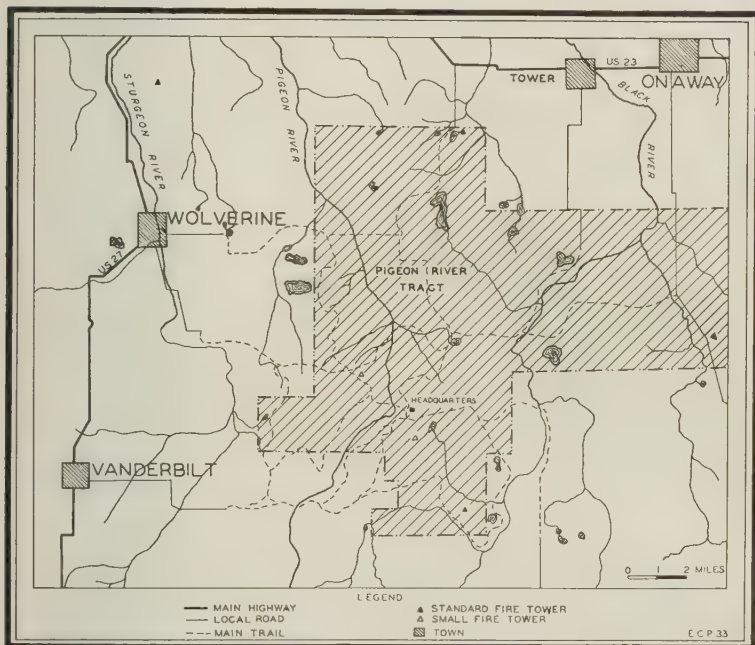
PIGEON RIVER PROJECT

The Pigeon River tract involves a type of land use very different from that of Escanaba and St. Ignace, which are used as overnight stopping places; from that of Munising, where there are special features for sightseers; and from that of Les Cheneaux, which is exclusively a resort development. It lies in the northern part of the Lower Peninsula and can be reached from the main routes of travel to the "Straits" (Map 27). The casual sightseer does not know it is there, since it is isolated from these routes.

The State Department of Conservation fell heir to several thousand acres of this land, owing to the fact that former owners could not afford to keep up the taxes on the land once the timber had been cut off, and there seemed to be no other good economic use for it. The Department has added to its original holdings by purchasing several thousand acres more, so that it now owns outright about four townships. Two state forests, a game preserve, and a large area of public hunting land have been established in this tract. Much time,

thought, money, and labor have been poured into these projects, which have resulted in the tract becoming one of the major projects of the Department.

The area is composed of sharply defined moraines, a little till plain, and a great deal of outwash plain. Two large rivers drain



MAP 27. The Pigeon River tract in Otsego and Cheboygan counties

through it, and many kettle and pit lakes are in it. The streams are excellent trout water, and the improvements that have been made on them will bring about an even better habitat for trout. During the trout season many fishermen come to this tract and set up camp. Deer and small game abound, especially on the borders of the game preserve. The area has been lumbered, but since it has not suffered greatly from fire, the second-growth cover develops unusually well. In some sections, where fires have destroyed the cover, plantings have been made, and the present plan is to manage the tract in such

a way that in the course of time it not only will have a good stand of timber but also will be a wilderness park serving hunters and fishermen as well as attracting those who wish to camp in the wilds and study nature. In a number of states the aesthetic value of our wild lands has been largely overlooked in the conservation movement, but in Michigan some attention is being paid to it. It has been found that a live deer which a tourist can see in its native habitat is a great attraction and draws city dwellers to the wild lands for their vacations. If these visitors can see some wild animals in their native habitats, the trip is a success, and they come again. If vistas are cut in the forests, the tourist can see the lay of the land better, and the monotony of continuous forest or brush is avoided, making his trip more interesting. These are some of the things that are now making the Pigeon River tract inviting to tourists. It is already starting to function as a magnet to draw people north, just as the Pictured Rocks do, and thus it serves several functions.

Projects of this sort are absorbing several hundred thousand acres of the so-called waste lands of the state. They are not really "waste lands," but merely "idle lands," and are gradually being converted into use by the recreational industry. The aesthetic use of wild land does not interfere with its use for forest products or for by-products like game, fishing, and nature study.

SUMMARY

This study is an attempt to present briefly several phases of the recreation industry as it is developing in Michigan. The types chosen are not all-inclusive but merely representative. Escanaba and St. Ignace serve the tourist exclusively; Munising acts as a magnet to draw people north and also serves the tourist as well as the resorter; Les Cheneaux are a resort region with relatively little tourist trade; and the Pigeon River tract is an example of the extensive use of idle land for a wilderness park, comprising timber growing, hunting, fishing, and other outdoor recreation. These are only types, since there are dozens of other localities which are functioning in a similar manner.

Land and resources that would otherwise be idle are being put to work through the recreational industry and are providing employment for thousands of local residents who would otherwise have to move away and seek employment elsewhere.

Not one of these resources is unusual or exceptional, and the writer has no idea of suggesting that Michigan is better equipped for recreation than are other states or that the state has anything to boast of in this line, but the intent is to show how very ordinary resources can be put to use and provide employment and thus allow an area to develop.

MICHIGAN STATE COLLEGE
EAST LANSING, MICHIGAN

FUNCTIONAL AREAS OF DETROIT, 1890-1933 *

LEONARD S. WILSON

THIS study of the growth and change in the functional areas of the city of Detroit presents a portion of the uncompleted story of the growth of the city. In preparing the material plotted on the accompanying maps an attempt was made to relate the evolution of the various divisions of Detroit to the data of the United States censuses. The procedure outlined below might well be followed in constructing functional maps in the historical growth of any city.

METHOD

The technique followed in working out this series of maps combines the discipline of the historian with that of the geographer. Since all the functional maps present landscapes which are at least ten years old, the entire work of delimiting the divisions of the city was related to the available documentary evidence on its growth.

The most important single source of information was the city directories for the years under consideration.¹ These publications, compiled during the years discussed, present material which accurately lists all the buildings in the city, with the address and the use of each. From these sources, checked through the office of the city engineer, it was possible to locate within a block the entire structure of Detroit. However, with the exception of the manufacturing and commercial buildings, the Polk directories gave no clue to the function of the individual structure in relation to the city as a whole. Consequently, it was necessary to consult records of dwellings as they existed in the period under consideration.

Aside from the purely physical information contained in the

* The field work done in connection with this paper was made possible by the granting of a Fellowship in Geography by the Earhart Foundation for Research in Metropolitan Detroit.

¹ Polk, R. L., *Directory of the City of Detroit*. R. L. Polk, Detroit, Michigan, 1891, 1901, 1911, 1921.

directories, other historical sources pertaining to the city were investigated to learn the location of each class of dwelling. Among the more important historical papers dealing with this subject are the various local histories.² First- and second-class residences were plotted from sources similar to those mentioned above, and court calendars, newspapers, and police items tended to indicate the location of the poorer residential areas.³ From these sources an accurate picture of the history of the city could be had. By the correlation of this history with the information previously mentioned as to the buildings of Detroit, the accompanying series of functional maps was prepared. As an explanation of the growth of the city, a brief account of the historical development of the urban area is included with the description of each map. This account describes the changes in the functional areas.

MAP FOR 1890

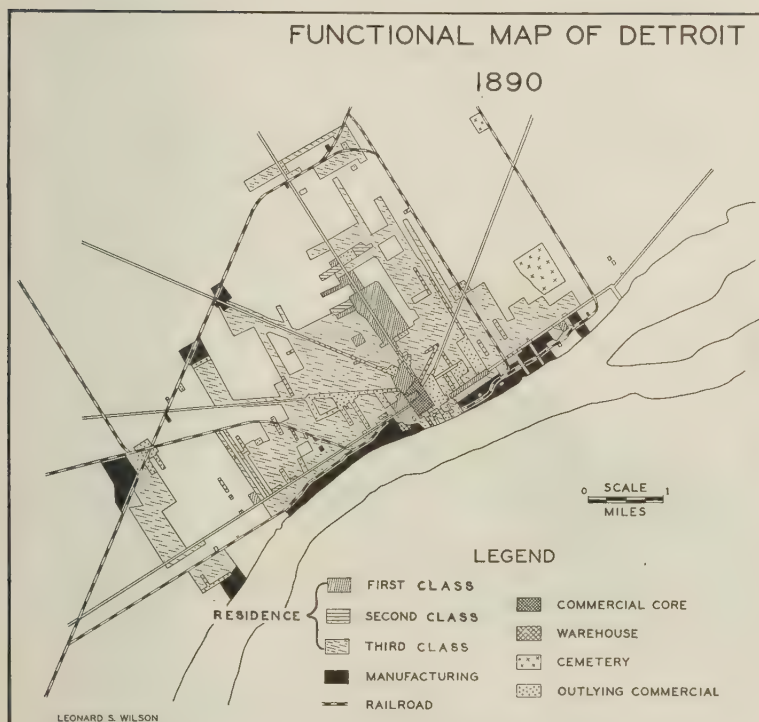
(Map 28)

Prior to 1890 the city of Detroit was primarily a one-industry town. The copper and the iron deposits in the Upper Peninsula of Michigan had been worked, and the smelting industry was of fundamental importance. This industry, combined with a smaller amount of lumbering and commerce, was the main source of employment in the city. By 1890 these industries, augmented by the addition of several small manufacturing plants, had developed the following pattern.

Industry was located within the city in a long narrow zone, interrupted only by Woodward Avenue, along the Detroit River. The Inner Belt Railroad had been built during the previous decade and the beginning of industrial replacement begun. Apparently the crossing of the Michigan Central Railroad and the Grand Trunk Railroad produced a satellite core beyond the city proper. The development, known as West Detroit, grew around a large stockyard located here. Shortly afterwards, several industries, formerly situated around the river front, moved into this new center because of congestion in the downtown area. Other beginnings were made on West Jefferson Avenue, the Milwaukee Junction section, and at

² Histories of the city are best exemplified by Silas Farmer, *History of Detroit*. Farmer and Company, Detroit, 1884.

³ Another important source was the Burton Historical Collection, of the Detroit Public Library.



MAP 28

the crossing of the main roads and the railways. These functional units in turn attracted associated groups. Small stores serving local needs followed the industrial development and in turn attracted small areas of third-class residences. Thus small independent areas composed of the three functional units mentioned above were established beyond the limits of the city proper.

The commercial areas, which, on the basis of function, may be divided into commercial core and outlying commercial, were located along the five main radial streets (see Map 29).⁴ The commercial core was bounded by Woodward, Jefferson, Cass, and Michigan av-

⁴ The five radial streets referred to are Woodward Avenue, Gratiot Avenue, Grand River Avenue, Michigan Avenue, and Jefferson Avenue.



MAP 29

enues. On the southern and the eastern sides an area of outlying commercial development was established in several blocks between Jefferson and Gratiot avenues. The beginning of the important rôle played by the five radial streets appeared. Commercial development took place on Jefferson, Michigan, Grand River, Woodward, and Gratiot avenues, the attraction being the establishment of city markets at the limits of the town. Secondary commercial streets became apparent chiefly in the area east of Woodward Avenue, which had formerly been the site of first-class residences. The ribbon pattern of commercial development followed the extension of these streets, which were drawn north during the decade 1880-90 by the increase in the importance of Milwaukee Junction. Other important

locations were found along north-south streets between Michigan and Jefferson avenues on the west side and between Jefferson and Gratiot avenues on the east side of the commercial core. One more commercial area was started on north Woodward Avenue in the vicinity of the present-day Grand Boulevard.

First-class residences were confined to the blocks on either side of Woodward Avenue north of Grand Circus Park, the area around Washington Boulevard, West Fort Street, and Jefferson Avenue, east of Woodward Avenue. A few people were beginning to move into the vicinity of the old race track, where the Indian Village development of today is located.

Second-class residences were practically nonexistent, being confined to a small area near the junction of Grand Boulevard and Jefferson Avenue. Another small area was on the Boulevard near the junction with Woodward Avenue.

Third-class residences made up the major portion of the city. In outlying districts these dwellings were composed of one- and two-story frame buildings. In the center, near the commercial core, and especially west of Woodward Avenue and south of Michigan Avenue, were old second-class residences. It is probable that this section may have been the slum area of the 1890's.

MAP FOR 1900

(Map 30)

During the 1890's the automobile industry started. At first the process was merely an assembly of parts manufactured in plants which normally dealt with portions of the machine, such as motor castings and wagon bodies. The motor blocks, for example, were manufactured under contract by the several iron foundries and smelters associated with the earlier concentration on ores from the Upper Peninsula. Bodies were furnished by the wagon companies already established, so that during the infancy of the industry no radical changes in the manufacturing section were made. The automobile industry merely occupied structures abandoned by other industries.

In 1900 the manufacturing developments remained closely allied with the transportation systems. The majority of these plants were along the bank of the river south of Jefferson Avenue. There was, apparently, a continued growth in the direction of the railroads,

with a slight increase in areal extent indicated in all sections. The satellites at Milwaukee Junction and West Detroit continued to grow.

The commercial core had expanded until it reached from the river along Woodward Avenue to the southern border of Grand



MAP 30

Circus Park. It is interesting to note that for ten years this small boundary acted as a barrier to northern expansion. This functional unit also occupied the former first-class residential area on Washington Boulevard and had taken over a considerable portion of outlying commercial property between Gratiot and Jefferson avenues, as well as the first-class residences on Fort Street.

This period also saw the further development of the five radial

streets along commercial lines. Jefferson Avenue became a commercial street as far east as the Inner Belt Railroad. Russell Street was of secondary importance as a commercial thoroughfare, while the roads between Russell Street and Woodward Avenue as far north as Gratiot Avenue began to show a skeletal structure of commercial buildings.

Residential areas as a whole tended to fill in the unoccupied land within the city. The first-class areas on Woodward Avenue contracted because of the expansion of the commercial areas. Washington Boulevard was entirely given over to commerce, and new concentrations appeared along West Grand Boulevard at Woodward Avenue, on East Grand Boulevard, and on East Jefferson Avenue beyond the Boulevard.

Second-class residences continued to be closely allied with first-class dwellings. They all occupied adjoining areas and tended to act as buffer zones between first- and third-class residential areas.

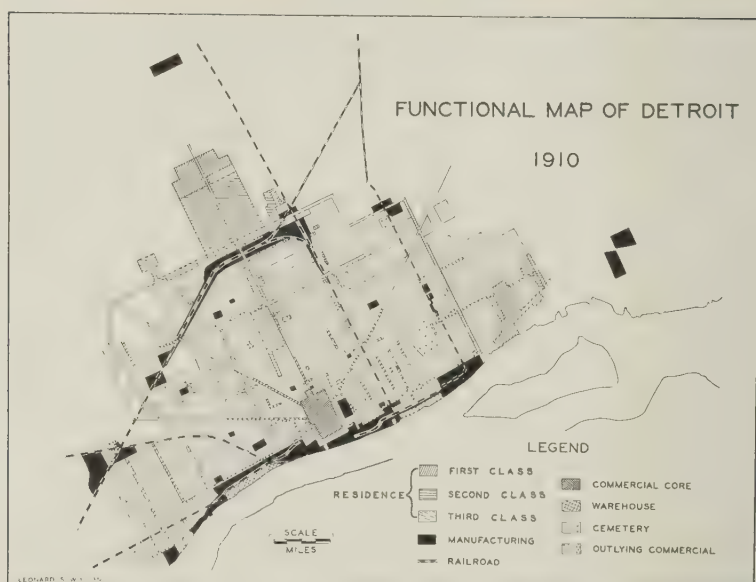
The greatest change occurred in the third-class residential areas. These continued to expand, filling in the vacant areas within the city and making ribbon-like extensions along streets leading to outlying commercial centers and toward the intersections of the five radial streets with the railroads. For the first time in the years studied this type of dwelling succeeded in surrounding the older first- and second-class residential areas.

In 1900 warehouses were scattered for the most part throughout the transportation area, with a heavier concentration along the river than elsewhere. It was during the preceding ten-year period that the trade commodities of the city changed from raw or semiprocessed materials to manufactured articles which had to be protected from the weather.

MAP FOR 1910

(Map 31)

By 1910 motor-car manufacturing had become firmly established in the industrial life of Detroit. As a result the industry began to occupy its own buildings, which, because of the crowding of the downtown river area, had to seek other places of attachment. A comparatively rapid growth took place, an early indication of what was later to develop into one of the most disorganized urban agglomerations in the United States.



MAP 31

Industrial property showed a marked departure from the close formation of the preceding decades. This was caused primarily by the expansion of the automobile industry. Ford built his Highland Park plant in the latter part of the decade. On East Jefferson Avenue, beyond the city limits, Continental Motors, Hudson Motors and Chalmers Motors were established. Automobile factories acted as magnets, drawing the city out toward them. At this time, too, the motor-car industry was plagued by "fly-by-night" concerns which sprang up in less favorable locations. For the most part these were located in abandoned factories near the downtown section. Here one other important change occurred, namely, the retreat of the industrial area served by both the river transports and the railroads; it was invaded by large warehouses, which became an important feature in the industrial scheme of Detroit.

The commercial core had nearly doubled in area. It extended from Jefferson Avenue north along Woodward Avenue to the third block beyond Grand Circus Park. In width it encompassed most

of the area between Cass Avenue and Brush Street. A considerable portion of this expansion may be accounted for by the increase of real estate offices and of branch offices of various industries which served the manufacturers of automobiles. In addition, many new stores were opened; theaters and hotels were built in the vicinity of Grand Circus Park, and the trade in the commercial core expanded into new fields of endeavor. The southern limit contracted from the water front to Jefferson Avenue, and in this section was replaced with terminals of the cross-river transportation lines.

Outlying commercial areas continued to expand along the five radial streets, but with less rapidity, especially on Grand River and Woodward avenues. Many small stores that existed on the west side in 1900 had been abandoned by 1910. A more concentrated grouping of these establishments was found on streets connecting the main arteries with the outlying industrial plants. A shifting of the commercial center around Milwaukee Junction was also noticeable. During the period prior to 1910 Warren Avenue began to develop as a business street. A heavy concentration of stores serving the outlying residential areas sprang up and continued at least until 1920. Kerchival Avenue, on the east side, and Mack Avenue also began to expand as commercial roads. The size of the outlying commercial area on the east side of the commercial core declined, possibly because of the increased diversity of products handled in the core proper and the movement of people from the downtown section to the periphery of the city.

Residential classifications became more complex with the beginning of cheap rapid transportation for all. In 1910 the first-class residential districts had moved outward beyond the Boulevard. In the vicinity of Woodward Avenue and Boston Boulevard the major new area of first-class dwellings was established. It was on the very fringe of the city; only the Ford plant in the village of Highland Park was north of this district. Between the first-class dwellings and the Boulevard a large section of second-class dwellings grew up. Another first-class residential area was just east of the Boulevard, on Jefferson Avenue.

Between the first- and the third-class residences sections of second-class dwellings appeared as buffers between the two types of homes already noted. These concentrations were along Boston and Grand boulevards. A minor growth of dwellings in this classifica-

tion was located in Indian Village and on East Grand Boulevard near Jefferson Avenue.

Expansion in the residential classes was concentrated in third-class areas. Many of the old first- and second-class areas, especially along Woodward and Jefferson avenues, became rooming-house districts. In addition, the automobile industry attracted large numbers of people to the city, and these immigrants tended to locate close to the source of employment. This resulted in the beginning of the spread of subdivisions. Prior to 1920 the city was a compact unit, with major expansions along the five radial streets. The first large unsettled areas within the city proper are of this date. In all cases these are near third-class residential areas and railroads. This might be an indication of land speculation for industrial development.

MAP FOR 1920

(Map 32)

In 1920 the automobile industry was weathering its first depression; expansion had gone on at a very rapid rate and land values rose to unheard-of prices. Speculation, combined with a rapidly increasing population and cheap quick transportation, began to make its impression on this cultural landscape. There were large blocks of unoccupied land within the city. Commercial streets extended to the limits of the settled areas and beyond.

At this time manufacturing had almost abandoned the river front near the center of the city to warehouses, which had multiplied in number with the expansion of the motor-car industry. A few establishments connected with the refining of salt remained on the west side of the city. Nearly all others moved out to advantageous sites along the railroads. Notable areas of concentration were those at West Side Junction, formerly West Detroit, Milwaukee Junction, and the crossing of the Outer Belt Railroad. Other sections of the city in this functional class were located on Kerchival and Jefferson avenues.

During the same period the commercial core had expanded to a considerable distance north of Grand Circus Park along Woodward Avenue and had occupied a number of blocks on Michigan and Gratiot avenues, Fort Street, and Lafayette Boulevard. On the east side the boundary had moved outward to include a portion of the commercial area as far as Russell Street. The core proper had



MAP 32

not reëntered the zone between Jefferson Avenue and the river; it was entirely surrounded by outlying commercial zones.

The outlying commercial areas continued to expand along the five radial streets, in many instances beyond the built-up residential areas. Gratiot and Michigan avenues were paralleled by other commercial streets. Satellite centers grew very rapidly, especially those at Grand Boulevard, Woodward and Jefferson avenues, East Grand Boulevard, and Highland Park.

First-class residential areas continued to exist along Chicago Boulevard and in Indian Village, but many of the wealthier citizens had moved either far beyond the city to the small summer resort of Grosse Pointe or into apartment buildings, the area of which was just beginning to expand.



MAP 33

As before, second-class residential areas surrounded the first-class zones. In contrast to the 1890 era these covered more space than did the first-class sections, and growth continued in a northwest direction beyond Chicago Boulevard and north of Indian Village.

Third-class residential areas again showed the greatest change. These tended to follow the precedent started at the outset of the motor-car era, namely, to settle in the vicinity of the factories. Land speculation, combined with the universal use of automobiles, spread the city over a large area, leaving great blocks unoccupied within it.

MAP FOR 1933

(Map 33)

Map 33 indicates that the changes in the city which took place in 1910 and which were shown on the 1920 map as continuing actually did carry on until 1933-34. The only change that has taken place since the construction of this map is the removal of

a portion of the outlying commercial area and the commercial core. Apparently, the city is in a static condition so far as growth is concerned. If anything, it is contracting, both because of vacancies in commercial buildings and because of the actual removal of such structures.

CONCLUSION

In conclusion, a few generalizations are here made:

1. Improved transportation may be the cause of the spreading of the city over a larger area than is necessary for the inclusion of all functional units.

2. The reversal of the sequent occupance on major transportation routes is characteristic of modern urban growth. Prior to the motor-car era, outlying commercial development followed the residential occupation of any area. At present it tends to precede it.

3. In competition with industry, commercial developments in satellite areas tend to be forced to relocate, regardless of the favorableness of the site.

4. The circumference of a first- or second-class residential area by third-class dwellings appears to end the growth of the district as a member of either of these functional groups. Shortly after the enclosure the dwellings decline. The former occupants move to a different location, rooming and apartment houses begin to appear, and the function as an exclusive or a superior residential area ends.

ACKNOWLEDGMENT

Map 33 is reproduced through the courtesy of Mr. J. A. Russell, who constructed it while holding a fellowship under the Earhart Foundation for Research in Metropolitan Detroit. It is included in this paper to supplement the series of maps made by the author.

CARLETON COLLEGE
NORTHFIELD, MINNESOTA

GLACIAL-LAKE LEVELS INDICATED BY TERRACES OF THE HURON, ROUGE, AND CLINTON RIVERS, MICHIGAN

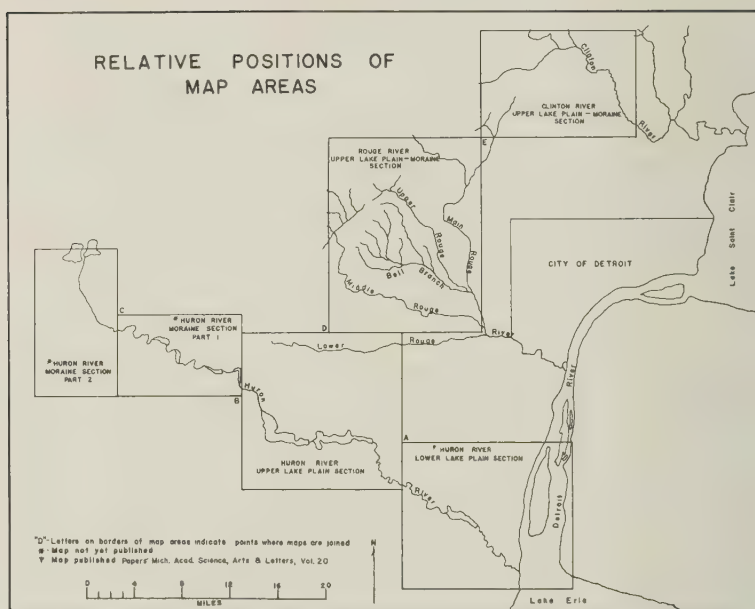
JAMES WILLIAM BAY

INTRODUCTION

THE rivers of southeastern Michigan originated as small streams flowing from the retreating ice front of the Huron-Erie lobe of Wisconsin glaciation. Their courses were at first northwestward to westward away from the ice front, or southwestward along the margin of the glacier.¹ As the glacier withdrew from the area and the series of glacial lakes began, new and lower base levels to the southeast were provided for these streams. By Lake Maumee time the drainage courses had become so altered that all the major streams flowed southeastward as tributaries to the lake. During the lake stages which followed, the valleys of these streams were lengthened at the mouthward end as rapidly as the lake waters lowered and exposed the lake bottom to erosion. As a result of these activities the drainage basins of the present rivers contain portions of the morainal area and of the subsequently formed glacial lake plain of this region.

Into this new terrane of morainal till and the clays, sands, and gravels of the lake plain each river has cut its valley. The unconsolidated materials have made it possible for the rivers to adjust their valleys to changing base levels. Thus, in spite of the relatively short time of each event, a rather complete record of the history is preserved in the terraces of the valleys. This record is of value as a verification or as a contradiction of the history which has been interpreted from the glacial and the glacial-lake features of the area.

¹ The direction of the retreat of the ice in this part of Michigan was south-eastward toward the low part of the Erie basin. For a brief discussion of events from the Wisconsin glaciation to the present time see I. C. Russell and Frank Leverett, "Ann Arbor Folio," *Geologic Atlas of the United States*, No. 155: 12-14. 1915.



In the valleys of the Huron, Rouge, and Clinton rivers are terraces which mark the flood-plain levels of these streams during the lives of several of the glacial lakes. The most significant of these terraces are found in the Upper Lake Plain section of each stream (Maps 34-37²). The area to be considered here extends about fifty miles along the upper part of the glacial lake plain in a northeast-southwest direction. It is a belt which lies between the moraines at the upper edge of the lake plain and the abandoned shore line of Lake Wayne, which is from six to twelve miles to the southeast.

² The glacial and the glacial-lake features are largely based upon the surface geology maps of the Ann Arbor, Romulus, and Wayne Quadrangles published by the U. S. Geological Survey.

Frank Leverett, of the U. S. Geological Survey, has very kindly consented to the use of certain portions of his manuscript maps of the Pontiac and Rochester Quadrangles and has offered valuable suggestions throughout this study. The writer is indebted to D. U. Gunter, W. G. Moore, and F. E. Stormer for their assistance in the field mapping and leveling work in the valleys of the rivers.

PLATE XLIV



FIG. 1



FIG. 2

Views, looking downstream, of terrace of Lake Wayne age cut in delta terrace of Lake Warren age, south side of Huron River valley, one mile west of Belleville (Fig. 1) and two miles west of Belleville (Fig. 2). The back slope of the delta terrace is one half to three quarters of a mile from these locations (see Map 35)

The Huron is the largest and most southerly of the rivers which flow across this belt, and it furnishes the type valley for the study of the terraces.

FEATURES OF THE HURON RIVER VALLEY

Map 35 of the Upper Lake Plain section of the Huron River shows three large terraces which correlate with the lake beaches crossing the valley. Miscellaneous smaller terraces exist downstream from the Wayne shore line, but are not to be considered at present. The oldest of the large terraces extends upstream from and correlates with the Whittlesey beach.³ A large portion of the town of Ypsilanti is built on this feature. It consists of bedded gravels, which presumably represent the delta of the Huron River deposited during Lake Whittlesey time in the still waters of an estuary before reaching the lake itself. The estuary had been formed by the Huron River cutting its valley to the low level of Lake Arkona and later becoming drowned when the water rose to the level of Lake Whittlesey. West of Belleville is a large terrace correlating with the Warren shore line,⁴ with upstream remnants cut in the terrace of Lake Whittlesey age. The Warren terrace, like that of Lake Whittlesey age, is a *delta terrace* and signifies a former lower stage of valley cutting before Lake Warren time. The third terrace begins back of the Wayne beach about two miles south of French Landing and extends upstream through French Landing and Belleville, and portions are cut in the Warren terrace west of Belleville (Pl. XLIV). The identity of the detached remnants of these three large terraces has been established by an extensive series of levels; sea-level elevations were measured along the entire length of each terrace.

Between the Whittlesey beach and that of Lake Wayne the Huron River deposited a large delta of the normal type, which covers an area of over fifty square miles. Most of this is believed to have been built into Lake Arkona. The map indicates that the Arkona, Warren, and Wayne shore lines take an arcuate path around this feature.

³ The terraces of Lake Whittlesey and Lake Warren ages in the Huron River valley were first described by Russell and Leverett (*op. cit.*, p. 14), but they stated at the time that "studies of the valley features were not sufficiently detailed to justify the complete mapping of each terrace or its coordination with the lake level to which it corresponds."

⁴ See note 3.

REGIONAL HISTORY SUGGESTED

The terraces and the large delta just described suggest the following events in the glacial lake history:

1. A low-water stage in Lake Arkona time existing while the Huron River built a large delta into the lake. The valley of the Huron River was cut to the low-water level of this lake.
2. Rise of the water to the Lake Whittlesey level, which caused the drowning of the Huron River at its mouth and the creation of an estuary in the valley. This was filled by sediments which the river deposited to form the *inset delta* or *delta terrace* upstream from the Whittlesey beach.
3. Lowering of the lake to a level at or below the Wayne beach.
4. Rise of the water to the Lake Warren level, which caused the deposition of the *second delta terrace* in the same manner in which that of Lake Whittlesey age was formed.
5. Lowering of the lake waters to the Lake Wayne level. The river adjusted itself to the new base level and cut the terrace which extends upstream through Belleville and which is *cut in the delta terrace* of Lake Warren age.

This order of events differs from the accepted history, as determined from the glacial lake shore features, in one important respect. The terraces indicate that Lake Warren was followed by either Lake Wayne or a second stage of Lake Wayne instead of by Lake Grassmere.

FEATURES OF THE ROUGE AND CLINTON RIVER VALLEYS

The River Rouge (Map 36) consists of several branches which began as separate streams that extended the mouthward portion of their courses across the lake plain as rapidly as the lake waters left the area. These did not become joined to form one river until Lake Elkton time. The Middle Rouge is the oldest and largest of the branches. The Clinton River (Map 37) is intermediate in size between the Huron and the Middle Rouge.

The maps indicate that there is a terrace of Lake Whittlesey age in the valleys of the Middle Rouge, the Bell Branch of the Rouge in Sections 6 and 7, Livonia Township, and the Clinton. These can be positively identified as being of the same age as the highest of the three Huron River terraces because of their relationship to the Whittlesey beach, which is practically an unbroken ridge over the entire distance. Furthermore, on the Middle Rouge and the Clinton the terrace contains bedded gravels. The absence of a ter-

race of Lake Whittlesey age on some of the streams suggests that they were too small at that time to adjust themselves to the changing base levels.

A terrace which corresponds to the lowest of the three Huron River terraces is present in the valleys of the Middle Rouge, the Bell Branch of the Rouge in Section 10, Livonia Township, the Upper Rouge, the Main Rouge, and the Clinton. These terraces are recognized by the fact that all of them, including that of the Huron, are at elevations close to 650 feet above sea level and are at or near the front of the large fan-shaped delta which had its origin in Lake Arkona time.

The middle of the series of three terraces is represented in the valleys of the Middle Rouge, the Bell Branch of the Rouge in Section 3, Livonia Township, the Upper Rouge, and the Clinton. These features are considered to be counterparts of the Huron River terrace of Lake Warren age because: (1) by Lake Maumee time the Huron, Rouge, and Clinton were subject to the same lake-shore conditions at their mouths, and therefore the Lake Plain sections of the valleys of each river should show the same number of large terraces; (2) the location is between the Whittlesey beach and the terrace of Lake Wayne age, both of which are easily recognized; and (3) the structure of this feature in the Clinton River valley is the same as that of the Huron. There are no exposures of structure in this terrace on the Rouge.

The relation of the Wayne terrace to the Warren is evident in the valleys of the streams which have both. The Clinton River furnishes an even more perfect example than the Huron; the terrace of Lake Wayne age extends upstream from Utica as a single unbroken feature one and one-half miles into the Warren. This relationship is also well illustrated in the Middle Rouge valley.

The delta of Lake Arkona age appears on the Rouge River map. On the Clinton River map it is suggested by the curvature of the shore lines as they approach the valley, but the exact boundaries have not been mapped.

Before proceeding further it should be noted that the correlation of the Whittlesey terrace on the various rivers was based largely upon its relation to a strong beach whose identity could not be mistaken at any point. The Wayne terrace was recognized principally by its elevation. Because of the fragmentary nature of the Arkona

beach are necessary. The crest line of this feature should be a reliable point to which levels can be run because it appears to be about the same height above the lake plain along its entire length. If tilting is displayed by the beaches, the terraces of the Saline and Raisin rivers to the south of the Huron should be mapped in order to determine where the tilting ceases. Should the Huron River prove to be just south of this point, the water level of Lake Whittlesey, to judge from elevations in the Huron River valley, would be about 724 feet above the present sea level, and that of Lake Warren about 677-678 feet.

SUMMARY

The Huron, Rouge, and Clinton rivers have an excellent record of their history preserved in the river terraces and deltas which are associated with these streams in the upper part of the glacial lake plain. These features are of value in studying the history of the glacial lakes that constituted the base levels to which the valleys were cut or filled. According to the method of correlation used here, the main terraces are of three ages: Lake Whittlesey, Lake Warren, and Lake Wayne or a second stage of Lake Wayne. From a study of these features the following additions or changes in the known glacial lake history of this region are indicated:

1. Lake Wayne or, possibly, a second stage of Lake Wayne followed Lake Warren. It was during the life of this lake that the lowest of the series of three terraces was formed in the river valleys studied.⁵

2. Points along the shore line of this lake are established by the lower extremities of the terraces correlated therewith, because these points represent the mouths of the rivers at that time. These should be an aid in the tracing of the lake boundaries, and the method is applicable wherever fragmentary beaches or tilting exists.

3. The water level of this lake was around 649 feet above the present sea level according to the elevations on the most downstream portions of the terraces.

⁵ The lake which immediately preceded Lake Warren has not been determined from a study of the terraces, but the *delta terrace* of Lake Warren age indicates that it was a low-water stage. Whether this lake was at or below the level of Lake Wayne can be determined by getting elevations at the base of the gravel in the delta terrace and comparing these with that of the Lake Wayne terrace where it is cut in the Warren.

D

HUR
UPP

C

Legend:

- Lake Elkton age
- Lake Whittlesey age
- GLA
- moraine: land-laid
- kame
- Glacial and Glacial Lake features are off
- Romulus, Ypsilanti, South

0 1

B





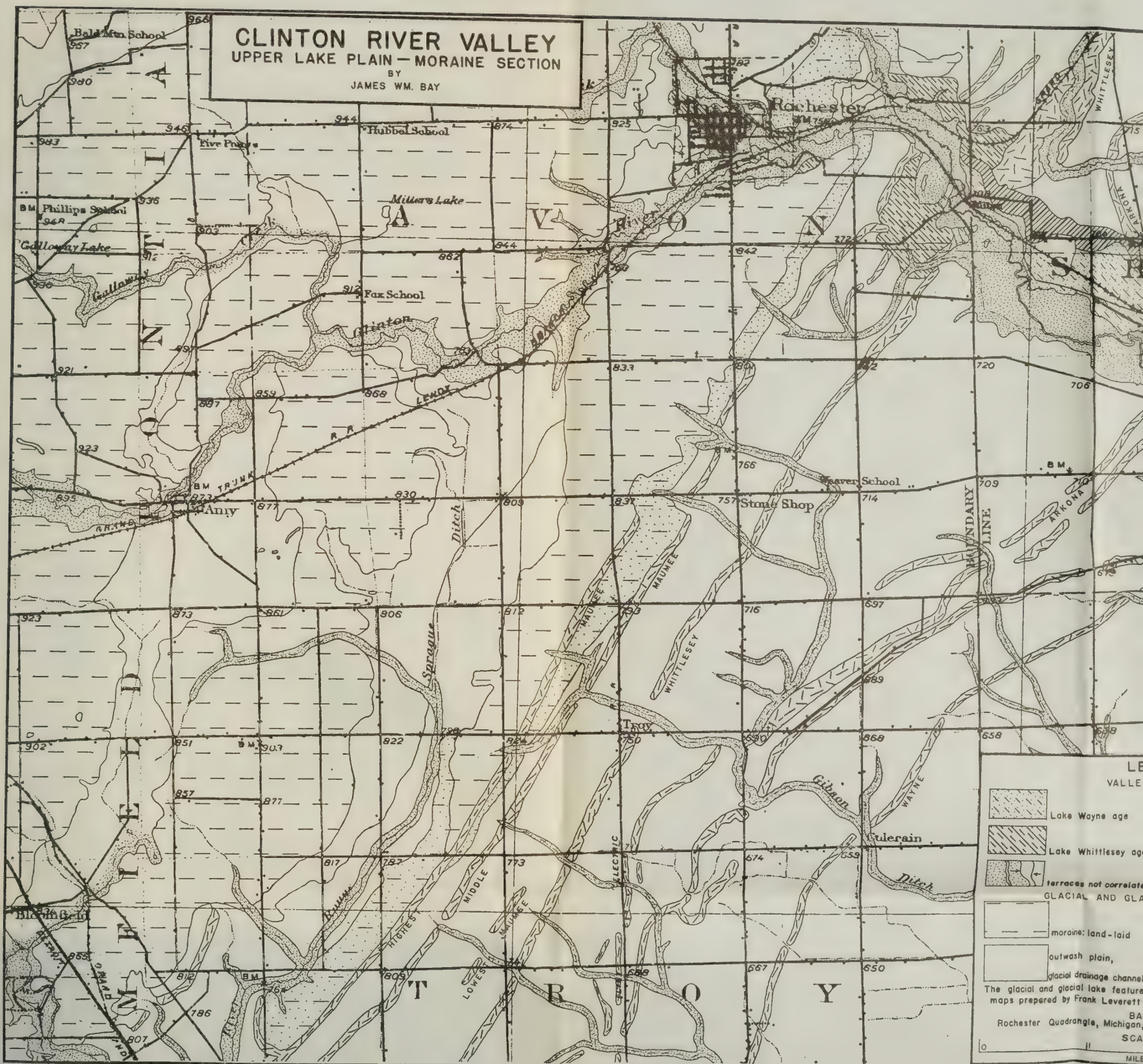
RIVER ROUGE VALLEY
UPPER LAKE PLAIN-MORaine SECTION

BY
JAMES WM. BAY



CLINTON RIVER VALLEY UPPER LAKE PLAIN — MORaine SECTION

BY
JAMES WM. BAY



LE
VALLE

Lake Wayne age
 Lake Whittlesey age
 terraces not correlated
 moraine land-laid
 outwash plain
 glacial drainage channel
 The glacial and glacial lake features
 maps prepared by Frank Leverett
 BA
 Rochester Quadrangle, Michigan
 SCA

0 1 MILE

THE CAMBRIAN-OZARKIAN CONTACT IN ALGER COUNTY, MICHIGAN

STANARD G. BERGQUIST

OF THE several counties situated in the Lowlands province in the eastern half of the Northern Peninsula, Alger is outstanding in possessing a wealth of natural scenic resources. This county, comprising an area of approximately 1,000 square miles, has a mainland water front of 83 miles along the south shore of Lake Superior (see Map 38). In this distance, and within a narrow belt extending inland some 8 or 10 miles from the present margin of the lake, numerous waterfalls, steep-walled rock escarpments, and shore cliffs find expression in the landscape.

During the summer of 1928 studies were undertaken of a large number of outcrops and rock exposures in Alger County, in connection with the work of the Land Economic Survey. An effort was made to work out, at least in part, the stratigraphic relationships and to account for the development of the major topographic features, particularly along the rim of the Lake Superior basin. Subsequent trips, together with laboratory studies of numerous rock samples, have made it possible to draw some rather definite conclusions relative to the geology of the area.

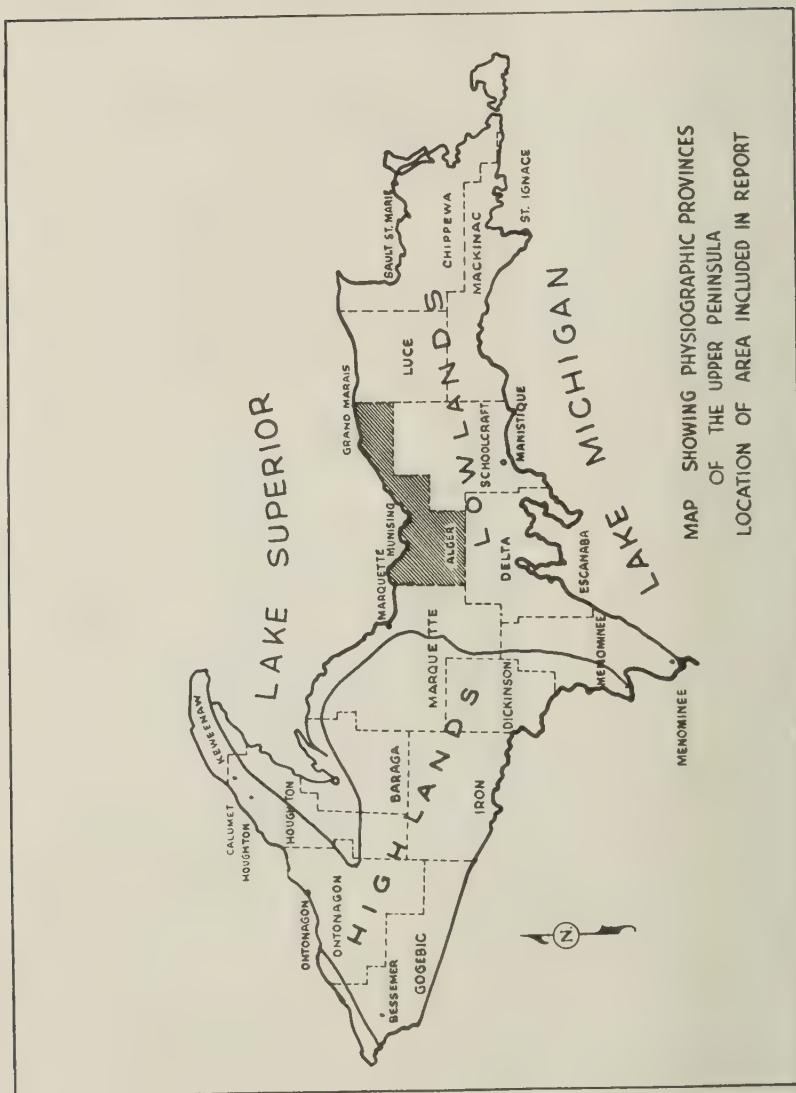
The text of this paper is concerned largely with that portion of the county in which the St. Croixan¹ series of the Cambrian system come in contact with the younger Hermansville calcareous formation (Map 39), which in Delta County Ulrich² and Hussey³ have tentatively assigned to the Ozarkian system. In an early report Rominger,⁴ however, classifies this formation, lying between the Cambrian sandstone and the Trenton limestone, as the Calciferous.

¹ E. O. Ulrich seems to have good evidence to support the view that the St. Croixan formation of the Wisconsin area extends into the Superior region of Alger County. The so-called Lake Superior sandstone would thus be included as a member of the formation. Personal communication, 1935.

² E. O. Ulrich, personal communications, 1930 and 1935.

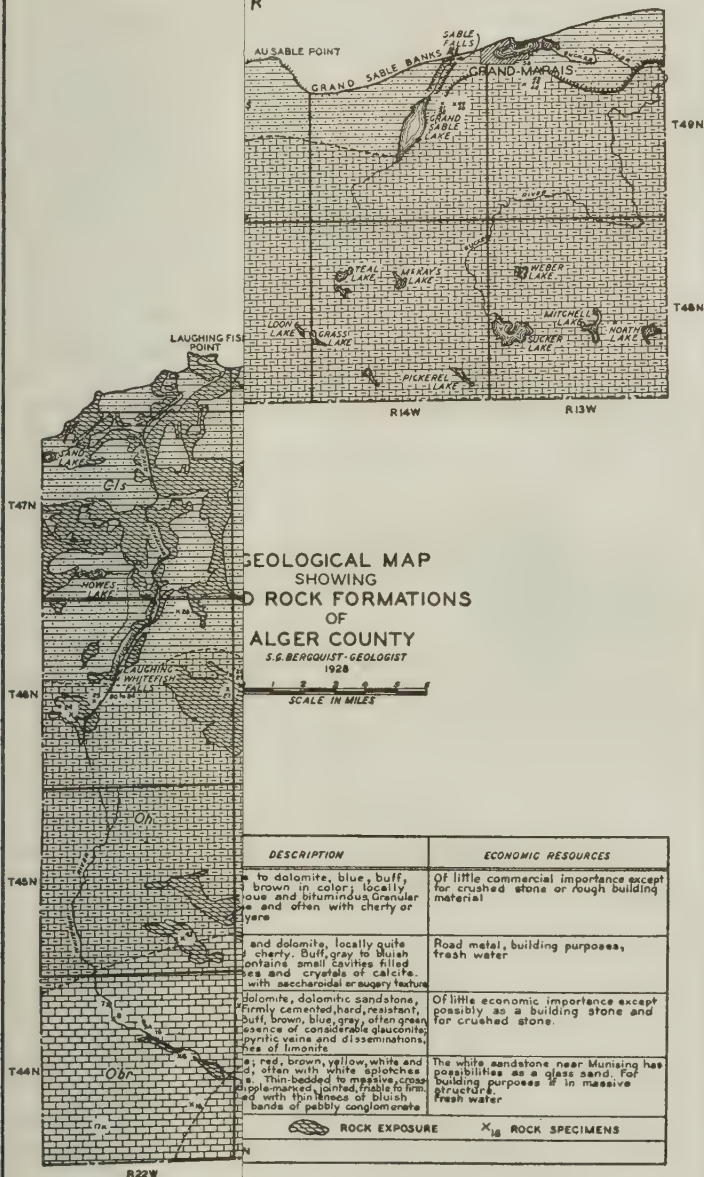
³ R. C. Hussey, personal communication, 1930.

⁴ Rominger, C., "Palaeozoic Rocks [of the Upper Peninsula of Michigan]," Part III of *Rep. Geol. Surv. Mich.*, I: 71-79. 1869-73.

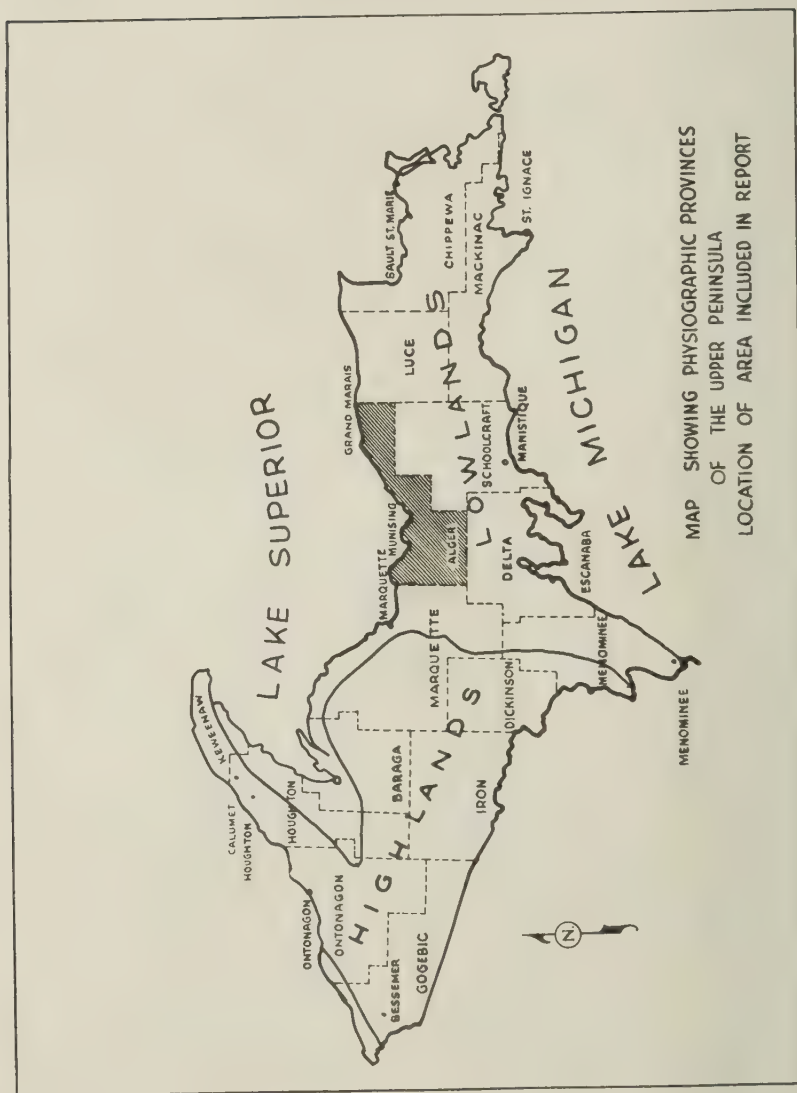


MAP SHOWING PHYSIOGRAPHIC PROVINCES
OF THE UPPER PENINSULA
LOCATION OF AREA INCLUDED IN REPORT

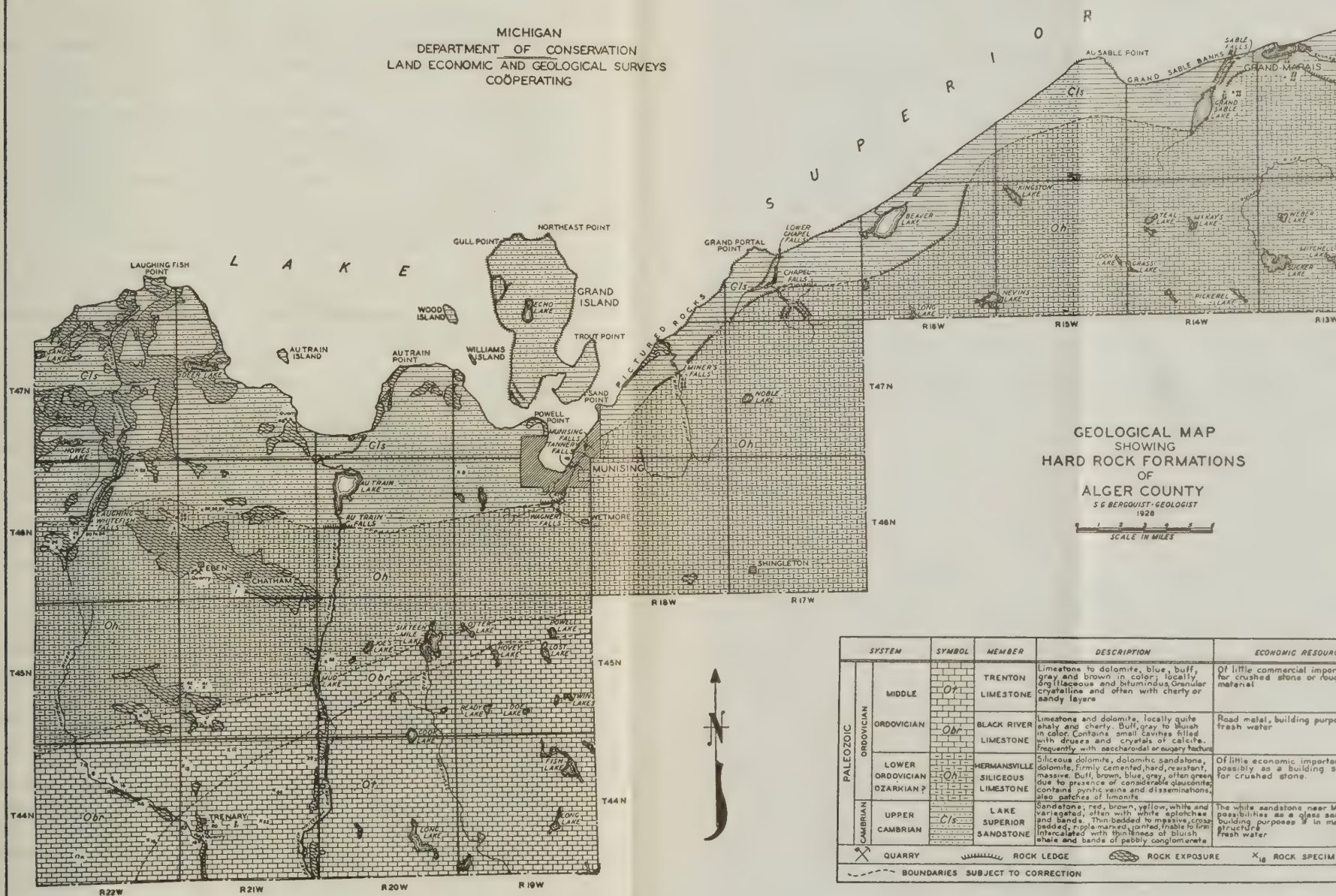
R



H-17



MICHIGAN
DEPARTMENT OF CONSERVATION
LAND ECONOMIC AND GEOLOGICAL SURVEYS
COÖPERATING



SYSTEM	SYMBOL	MEMBER	DESCRIPTION	ECONOMIC RESOURCES
PALEOZOIC	MIDDLE	TRENTON LIMESTONE	Limestones to dolomite, blue, buff, gray and brown in color; locally argillaceous and bituminous. Granular crystalline and often with cherty or sandy layers.	Of little commercial importance for crushed stone or rough material.
		BLACK RIVER LIMESTONE	Limestone and dolomite, locally quite shaly and cherty. Buff, gray to bluish in color. Contains small cavities filled with druses and crystals of calcite. Frequently with saccharoidal or sugary texture.	Road metal, building purposes, fresh water.
	LOWER ORDOVICIAN	HERMANVILLE LIMESTONE	Siliceous dolomite, dolomitic sandstone, dolomite, firmly cemented, hard, resistant. Buff, brown, blue, gray, often green due to presence of considerable glauconite, contains pyritic veins and disseminations, also patches of limonite.	Of little economic importance, possibly as a building stone for crushed stone.
		LAKE SUPERIOR SANDSTONE	Sandstones, red, brown, yellow, white and variegated; often with white spots and bands. Thin-bedded to massive, cross-bedded, ripple-marked, jointed, friable to firm. Intercalated with thinnesses of bluish shale and bands of pebbly conglomerate.	The white sandstone near Munising is a glass sand, building purposes, in mass for crushed stone, fresh water.
CAMBRIAN				
QUARRY ROCK LEDGE ROCK EXPOSURE ROCK SPECIMEN				
BOUNDARIES SUBJECT TO CORRECTION				

The area studied includes rock sections at numerous falls across the county where northward-flowing streams plunge precipitously over an escarpment wall from 50 to 100 feet high as they break into the Lake Superior basin.

Field investigations of the numerous falls in the county seem to bear out the observation that they owe their position in large measure to the presence of a hard, resistant cap rock fairly uniform in structure, but of somewhat variable thickness. Laboratory studies of samples from several sections along the escarpment show that the cap rock ranges in composition from dolomitic sandstone to siliceous dolomite. It rests unconformably upon the more weakly cemented and friable Cambrian sandstone below. The cap rock in the various exposures appears in the field to have somewhat striking physical similarities. Laboratory studies seem to bear this out and to prove without question that the rock composition within the formation is fairly consistent from one locality to another.

In the complete absence of megascopic fossils in the formations of the region it has been necessary to make correlations of the strata chiefly on the basis of lithological and chemical characters. Detailed comparative studies of a relatively large number of rock samples from numerous localities seem to present conclusive evidence that several distinctly different formations are exposed in vertical section along the walls of the escarpment.

The silicocalcareous cap rock is at present confined largely to the area south of the crest of the northward-facing escarpment rim. There is, nevertheless, good evidence to support the view that at an earlier date it covered a much more extensive area, even to the north of the present shore. In the northwest part of Grand Island, Sections 20 and 29, T. 48 N., R. 19 W., one may observe several patches of the cap rock exposed along the crest of the high marginal cliffs (Map 39). These exposures are the highest elevation on the island and appear to have no counterparts in the lower-lying areas. It is evident from these isolated and rather far removed outliers that the so-called Hermansville formation has undergone a great deal of recession by shore-cliff erosion. Much of the early erosional activity which took place in the region was undoubtedly associated with the movement of the Superior ice lobe through the basin in the Pleistocene epoch, and later still by the shore work of lakes Algonquin and Nipissing.

LAUGHING WHITEFISH FALLS

Laughing Whitefish River (Pl. XLV, Fig. 1), in the western part of the county, plunges over an escarpment to expose a cliff of 90 feet of sandstone in the NE. $\frac{1}{4}$, NW. $\frac{1}{4}$, SW. $\frac{1}{4}$, Sec. 16, T. 46 N., R. 22 W. In this exposure the upper 25 or 30 feet of the sandstone is quite massive in structure, cross-bedded, and grayish, and breaks in a vertical cliff. It is composed essentially of loosely consolidated, clear small grains of subangular and faceted quartz. Below this massive surface ledge the sandstone is thin-bedded and intercalated with laminae of blue shale. Here the slope of the falls becomes less abrupt, but the river has excavated a broad, extensive amphitheater in the formation below the crest of the falls (Pl. XLV, Fig. 2). Numerous water-worn caves have been sculptured in the rock wall some 20 feet below the break of the escarpment at the juncture between the more massive and the thin-bedded sandstones.

The crest of the falls is carved in a friable, easily eroded sandstone, which is being worn back to form a steep-walled gorge. The chemical analysis of a sample of the rock (specimen 34) taken from the upper brink of the falls definitely shows it to be sandstone, with a silica content of 98.97 per cent (see Table I). Lithological studies of the rock samples indicate conclusively that the high percentage of SiO_2 is largely in the form of quartz. The analysis shows a complete absence of calcareous cement.

A study of the surface petrology reveals no cap of hard dolomitic rock at the immediate crest of the falls. As a consequence of sapping the cliff is here retreating quite definitely. In the river bed an eighth of a mile upstream from the lip of the falls, however, may be found the contact between the lower siliceous sandstone and the hard, massive dolomitic sandstone above. The latter is composed of light to dark gray, translucent grains of quartz, cemented in a matrix of firm dolomite in which are also found partly rounded grains of calcareous minerals. The chemical analysis of the sample (specimen 31) shows the silica content reduced to 50.90 per cent. The oxides of calcium and magnesium and the carbon dioxide together make up a total of 49.32 per cent of the composition, thus evidencing a high degree of dolomitization (see Table I).

The Hermansville cap rock in this locality is relatively thin and is being worn back rather rapidly by the swift-flowing waters in the

TABLE I
SUMMARY OF ROCK ANALYSES

Rock sample	Locality	Position	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	Na ₂ O	K ₂ O	MgO	TiO ₂	P ₂ O ₅	CO ₂	SO ₃	Mn ₂ O ₄	R ₂ O ₃	Moist.
31	Laughing Whitefish Falls	Cap rock Crest of falls	50.98	None	1.21	15.76	None	None	10.36	Trace	0.21	23.20	Trace	0.18	...	...
34			98.76	0.03	0.35	0.80	None	None	0.30	Trace	0.35	None	None	0.01	...	...
35	Rock River escarpment	Cap rock - 35 feet	62.13 98.15	9.22 0.20	1.86 0.16	11.58 0.50	None 0.28	0.92 None	4.25 0.90	0.15 Trace	0.30 0.20	9.23 None	Trace Trace	0.13 0.19	...	...
60' (A. T.) 1' (A. T.)	Au Train Falls, upper Au Train Falls, lower	Cap rock - 90 feet	33.02 30.58	4.90 1.11	0.72 1.81	19.05 20.35	0.24 0.78	0.31 0.21	13.05 13.63	0.02 Trace	0.19 0.08	29.70 33.10	Trace 0.20	0.12 0.21	...	...
1 (W. F.) 48 (W. F.)	Wagner Falls	Cap rock - 36 feet	43.52 38.70	2.95 None	2.25 0.37	15.75 0.99	0.46 0.27	1.64 0.09	10.73 None	Trace 0.02	Trace 0.03	24.40 None	None None	0.24 0.01	...	...
48	Tannery Falls	Cap rock	60.68	Trace	1.23	11.95	0.07	0.20	10.18	None	0.27	17.10	None	0.21	...	...
69	Munising Falls	Cap rock - 16 feet	64.11 94.20	0.60 2.88	0.63 0.37	11.07 2.00	0.27 None	0.40 0.27	7.07 1.10	0.04 Trace	None 0.04	16.40 1.20	None None	0.13 0.02	...	...
62 63	Miner's Falls	Cap rock - 18 feet	36.00 90.26	1.87 5.48	1.53 0.13	18.45 0.57	0.27 0.46	0.09 1.84	11.70 0.60	0.13 0.02	0.13 0.18	30.80 None	Trace 1.00	0.21 0.01	...	...
59	Miner's Castle		79.80	12.70	1.28	0.32	2.30	2.40	0.78	0.24	0.18	None	0.55	Trace	...	...
C.F. a C.F. b	Chapel Falls	Cap rock - 15 feet	40.69 98.82	0.13 0.53	1.61 0.20	18.21 0.04	0.07 0.06	0.15 0.19	12.40 0.28	Trace Trace	0.05 0.01	26.59 0.006	0.58 0.02	0.29 Trace	1.79 0.74	0.10 0.11
56a 57	Sable Falls Lower Algonquin	Brink Shore cliff	85.38 50.61	2.26 None	0.75 2.20	2.55 14.60	0.42 0.09	1.85 None	2.18 10.03	0.07 0.02	0.30 0.30	3.00 23.00	Trace Trace	None 0.27	...	...
53	South of Grand Marais	Shore scarp cap	50.16	None	0.30	15.24	None	0.17	9.73	0.63	0.15	24.20	None	0.06	...	...
58	Chipmunk Falls	Below cap rock	92.57	1.07	0.64	3.31	None	0.60	2.16	0.05	0.20	None	None	0.01	...	...

stream above the falls. At one time, in the earlier development of the escarpment, the resistant layer covered the Cambrian sandstone in this area entirely, as may be judged from its mantle occurrence outside of the channel. It must have exerted an important influence in erosional control during the youthful history of the falls.

In an early report of the Michigan Geological Survey Rominger⁵ described more or less completely the various layers of the Cambrian sandstone in the area of Laughing Whitefish River and Falls. In his report the siliceous sandstone is classed as the Potsdam formation.

ROCK RIVER ESCARPMENT

The escarpment wall which constitutes the south slope of the South Branch of Rock River, in the SW. $\frac{1}{4}$, NW. $\frac{1}{4}$, Sec. 17, T. 46 N., R. 21 W., is capped with a hard, resistant dolomitic sandstone which measures 35 feet in thickness. This extremely fine textured rock is composed of minute subangular grains of quartz firmly cemented into a matrix of dense, compact dolomite. It is grayish, with local brown streaks and stains due to the presence of small amounts of weathered iron oxide. It contains 62.13 per cent of SiO_2 , mostly in the form of quartz, in addition to appreciable amounts of lime, magnesia, and carbon dioxide (specimen 35; see Table I). The dolomitic sandstone rests directly upon a light-colored siliceous sandstone, which is composed essentially of loosely cemented subangular grains of quartz. The underlying rock is nonresistant and friable and has been extensively undercut by river action. The analysis shows this rock (specimen 37) to be extremely siliceous and to contain no calcareous cement (see Table I).

AU TRAIN FALLS

Au Train Falls (Pl. XLVI, Fig. 1), on Au Train River in the NW. $\frac{1}{4}$, SE. $\frac{1}{4}$, Sec. 31, T. 46 N., R. 20 W., exposes a section of siliceous dolomite with an aggregate thickness of approximately 100 feet, as measured from the crest of the upper falls to the base of the lower falls. In this locality the river descends over two abrupt breaks, which are separated by a rather strong cataract. The rock slope of the two falls is steplike in character, owing to differential erosion on the alternate thin beds of dolomite and shale in the formation.

⁵ *Op. cit.*, pp. 88-90.

Specimen 60 A.T., taken from the crest of the upper falls, has an analysis which characterizes it as siliceous dolomite (see Table I). This rock is more highly dolomitic and contains less silica than the cap rock which is exposed in the river channel above Laughing Whitefish Falls. Much glauconite and pyrite are disseminated through the rock section, as has been noted in a previous paper.⁶

At the base of the lower falls, or Power Falls (Pl. XLVI, Fig. 2), directly above the contact with the Cambrian sandstone, the rock is light brown and somewhat weather-banded. It is more friable and less resistant than that which forms the crest of the upper falls. Disseminated pyrite has in part been oxidized into limonite, which is present as a brownish stain throughout the rock mass. The analysis (specimen 1 A.T.) is essentially the same as that for the sample from the upper section (see Table I).

The escarpment at Au Train Falls presents the thickest exposure of Hermansville formation to be observed in the county. The base of the dolomite rests directly upon a brownish, ferruginous sandstone composed essentially of rounded to subangular grains of loosely cemented quartz, the Cambrian, through which the lower gorge has been excavated. As the river leaves the gorge it follows a broadly meandering course across the Nipissing sand plain before finally entering Lake Superior, near Au Train.

WAGNER FALLS

The section at Wagner Falls (Pl. XLVII, Fig. 1) on Wagner Creek, in the NW. $\frac{1}{4}$, NE. $\frac{1}{4}$, Sec. 14, T. 46 N., R. 19 W., exposes 36 feet of upper cap rock varying in composition from siliceous dolomite to dolomitic sandstone. The rock is grayish, hard, and resistant, and contains an abundance of glauconite and some pyritic disseminations. It is composed of subangular grains of quartz firmly cemented in a ground mass of dolomite (see Table I, specimen 1 W. F.). At a depth of 36 feet below the crest of the falls the rock changes abruptly into a sandstone, composed essentially of loosely cemented grains of quartz. The chemical analysis of a sample of this rock (specimen 48 W. F.) shows that it contains 98.70 per cent of silica, with no calcareous cementing material (see Table I). The upper 36 feet of

⁶ Bergquist, S. G., "The Occurrence of Glauconite in the Hermansville Formation of Alger County, Michigan," *Pap. Mich. Acad. Sci., Arts and Letters*, 12 (1929) : 231-237. 1930.

siliceous dolomite which forms the resistant crest rock of Wagner Falls is unquestionably Hermansville of Ozarkian age; the underlying, loosely consolidated sandstone belongs to the St. Croixan series of the Cambrian.

TANNERY FALLS

The crest of Tannery Falls (Pl. XLVIII, Fig. 1), near Munising, in the SE. $\frac{1}{4}$, NW. $\frac{1}{4}$, Sec. 1, T. 46 N., R. 19 W., exposes a buff-colored, dolomitic sandstone made up largely of subangular grains of quartz embedded in a matrix of dense, firm dolomite. The rock is hard and resistant and forms a section about 12 feet thick, resting directly upon a weak, loosely cemented, and easily weathered sandstone. A steep amphitheater-like gorge has been sculptured in the sandstone for a considerable distance below the falls, and undercutting is still in progress in the weaker formation which underlies the cap rock (Pl. XLVIII, Fig. 2). A sample of the rock (specimen 48), taken from the upper portion of the 12-foot cap, was found by chemical analysis to contain 60.68 per cent of SiO_2 , 11.95 per cent of CaO , 10.18 per cent MgO , and 17.10 per cent CO_2 , making it definitely a dolomitic sandstone (see Table I). Although no samples of the lower rock were analyzed chemically, petrologic examination indicated a predominance of quartz, with little or no trace of calcareous substance in the cement. The large amount of gorging which has taken place in this area was probably due to more rapid stream erosion as related to the thinness of the dolomitic cover.

MUNISING FALLS

Munising Falls (Pl. XLVII, Fig. 2), in the NE. $\frac{1}{4}$, SW. $\frac{1}{4}$, SE. $\frac{1}{4}$, Sec. 36, T. 47 N., R. 19 W., owes its existence to a hard, resistant cap rock of dolomitic sandstone which is 15 feet thick. The rock consists of light to dark gray subangular and rounded grains of quartz firmly cemented in a matrix of dolomite. It contains 64.11 per cent of silica and appreciable amounts of calcium and magnesium oxides, as well as carbon dioxide (see Table I). At a depth of 15 feet below the surface the rock breaks into a light brown rather weak sandstone, which has been extensively undercut. This part of the section resembles greatly the lower sandstone which is exposed in the Tannery gorge. The composition (specimen 69) is largely silica, with but very small amounts of lime, magnesia, and carbon

dioxide (see Table I). The contact between the upper or Hermansville and the lower or Cambrian formations is distinctly marked at a depth of 15 feet below the crest of the falls, where it may be traced with comparative ease along the ledges of the gorge. Here again, as at Tannery Falls, the surface-resistant layer overhangs the lower undermined weaker sandstone. Numerous potholes, churned out deeply in the sandstone floor at the base of the falls, are expressions of the weak character of that rock.

MINER'S FALLS

A vertical section approximately 100 feet thick is exposed in the falls on Miner's River (Pl. XLIX, Fig. 1), in the SE. $\frac{1}{4}$, NE. $\frac{1}{4}$, NE. $\frac{1}{4}$, Sec. 15, T. 47 N., R. 18 W. The mantle rock at the falls is a firm, resistant, siliceous dolomite and forms a layer 18 feet thick capping the sandstone. It is light to dark gray, fine in texture, and is composed of rounded grains of translucent quartz firmly embedded in a matrix of dolomite cement. It is pitted with small weather pockets and solution cavities, some of which are lined with minute crystals of calcite. Glauconite is disseminated through the basal portion of the dolomite, where it is in contact with the subjacent sandstone, but it constitutes a very small proportion of the rock. The uppermost layer of rock in this area, as represented by an average sample (specimen 62), has a composition which is not much unlike that of the corresponding formation at Au Train Falls (see Table I). The Cambrian sandstone, which directly underlies the dolomite cap, is grayish, weak in structure, and easily eroded. It is composed essentially of very fine grains of subangular quartz set into a siliceous and more or less argillaceous cement. The sandstone of this section contains a slightly lower percentage of silica, but a relatively higher content of alumina than do the samples of the same horizon in other areas along the escarpment (specimen 63; see Table I).

THE PICTURED ROCKS

One of the most imposing geologic features within the county is that which is known as the Pictured Rocks (Pl. L, Fig. 1).⁷ These formations extend more or less continuously from a point in the

⁷ A vivid description of the Pictured Rocks, with illustrations, is contained in one of the early volumes dealing with the geology of the state, by J. W. Foster and J. E. Whitney, *U. S. Senate Report of the Lake Superior Land District: Part II, The Iron Region together with the General Geology*, pp. 124-131. 1851.

SE. $\frac{1}{4}$, Sec. 17, T. 47 N., R. 18 W., directly east of Munising, eastward for a distance of approximately 13 miles, to the SE. $\frac{1}{4}$, Sec. 12, T. 48 N., R. 17 W., near Beaver Lake (see Map 39). The rocks rise out of Lake Superior as a range of bold mural cliffs, with sheer walls from 100 to 150 or more feet high. They are sculptured in the St. Croixan formation, which in this area assumes a variety of bright colors and brilliant hues. The dominant shades are red and brown, interspersed with tints of yellow and green. Distributed through the rock are numerous white circular blotches and occasional bleached-out lenses in which the ferruginous coloring matter has been removed. These lighter areas in the variegated and mottled sandstone may have been produced by the bleaching action of hydrogen sulphide, which was generated from included decaying organic matter, sulphate-reducing bacteria, or sulphide waters, according to the theory proposed by Keller,⁸ who states that "the solution of the ferrous iron must take place after reduction, by water and subsequent solutions affected by carbonate waters."

The sandstone of the Pictured Rocks varies in structure from a thin-bedded, cross-laminated, fine-textured variety to a massive, somewhat coarser but, nevertheless, weakly cemented and friable type. Occasional lenses of quartz conglomerate and thin layers of bluish shale are locally intercalated. At the edge of Lake Superior numerous caves have been undercut into the rock cliffs by wave action. The sandstone is divided by vertical joints into a series of close-fitting blocks. In the process of sapping along the joint openings, large sections of rock have been dislodged from the cliffs and heaped along the base of the bluffs, to be churned up by the ever-pounding surf. The cliffs are gradually being cut back in an echelon pattern, but continue to maintain a vertical face in spite of recession.

In the districts where the rock wall flanks the water's edge the sandstone has been largely stripped of its former cap rock of resistant dolomitic Hermansville formation, and erosion is gradually reducing the surface relief. The mantle rock can invariably be traced to the higher terraces a short distance back from the cliff face, where it affords a protective surface against excessive wear. Small residual outliers of the original cap have been preserved in the more sheltered areas along the shore, but are usually so small in extent as to be of little or no consequence in the present conditioning of the ledges.

⁸ Keller, W. D., "Red Bed Bleaching," *Am. Journ. Sci.*, 18: 65-70. 1929.

The turrets of Miner's Castle (Pl. L, Fig. 2), which is in the SW. $\frac{1}{4}$, Sec. 3, T. 47 N., R. 18 W., seem to rise above a beveled promontory which owes its development to the resistant nature of the rock mantle. The "Castle" itself is composed of material which is entirely unlike that of the sandstone in the main façade. It occupies a position which is considerably lower than the average level of the adjacent cliffs and seems to be set into an embayment or reëntrant in the older Cambrian rock mass. The rock in the turrets is tan to gray, and is composed of small rounded grains of quartz set solidly in a matrix of argillaceous cement. It has the appearance of being somewhat oölitic in structure and is resistant to weathering, as may be judged by the erosional remnants. Analysis of the rock (specimen 59) from the turrets shows it to contain 79.8 per cent silica, 12.70 per cent alumina, and but a small trace of calcium and magnesium oxides (see Table I). It will be noted from the analysis that the rock is a highly aluminous, argillaceous sandstone, quite different in composition from the average Cambrian sandstone in the area. On the other hand, it does not contain the calcareous cement which is characteristic of the Hermansville in the various exposures.

Slightly beyond the Grand Portal, and within three miles of the east end of the high cliff section of the Pictured Rocks, stand several water-carved monuments, commonly known as Pulpit Rock and the Chapel. The Chapel is sculptured out of the Cambrian sandstone at a height of 30 or 40 feet above the level of the lake, and was formed at a time when the lake level was higher than at present, probably during the later Algonquin and Nipissing stages. It has an arched roof of sandstone, some 20 feet in thickness, which is supported on four massive columns of rock. From the lakeside the structure presents the appearance of a natural rock-hewn chapel.

CHAPEL FALLS

At the south end of Chapel Lake, in Section 28, T. 48 N., R. 17 W., Chapel Creek breaks over the escarpment rim and plunges in a series of cascades across the Cambrian sandstone into the lake (Pl. LI). The outlet from the lake spills over a succession of low, gently sloping ledges of sandstone and discharges with a slight fall into Lake Superior, just to the west of the Chapel. The position of the upper falls on the escarpment is here, as in the other falls described, under control of the Hermansville cap rock. This formation, how-

ever, has been worn back in the river channel for a short distance upstream from the crest of the falls.

The analysis of the sandstone is almost identical with that of the similar formation at Laughing Whitefish Falls, whereas the cap rock approximates in composition that of the corresponding horizon at Wagner Falls (see Table I).

The "Rocks" continue, with gradually diminishing height beyond Grand Portal, for a distance of about 3 miles to the eastward. At that point they disappear into the sandy, dune-covered lake plain of the Beaver Lake basin. They are conspicuously absent along the shore for a distance of 12 miles beyond, but reappear at Au Sable Point, on the west end of Grand Sable Banks. Here they form a line of relatively low, undercut cliffs, which may be traced for a half mile or more along the shore near the lighthouse.

SABLE FALLS

Sable Creek, the outlet of Grand Sable Lake in the vicinity just west of Grand Marais, plunges over a 75-foot rock escarpment (Pl. XLIX, Fig. 2) before it reaches Lake Superior in Section 2, T. 49 N., R. 14 W. This feature is characterized by a series of cascades which have developed in a section of alternately hard and soft layers in the Cambrian sandstone. Thin beds of soft blue shale and hard pebbly conglomerate are intercalated with the sandstone and contribute to the cascade-like development of the falls.

The rock which forms the crest of Sable Falls is a slightly calcareous, cross-bedded sandstone composed of rounded grains of quartz with a silica content of almost 86 per cent. The formation is brownish, thin-bedded, and friable, and seems to be very susceptible to erosion. Analysis of specimen 56a, taken from the ledge at the brink of the falls, shows a relatively small proportion of calcium, magnesium oxides, and carbon dioxide (see Table I). The relatively high percentage of silica contained in the rock, together with its lithologic characters, seems to preclude its falling into the Hermansville formation. In physical characteristics and features it is related more closely to the Cambrian sandstone. No hard cap rock of siliceous dolomite is present at the immediate crest of the falls, since excessive erosion has caused its retreat upstream. The Hermansville forms the ridge of the Lower and Middle Algonquin shore scarps to the south of the falls, where it is exposed in the

cut at the highway crossing in the SW. $\frac{1}{4}$, SW. $\frac{1}{4}$, Sec. 1, T. 49 N., R. 14 W.

In this locality the exposed rock is a grayish, firm, resistant, siliceous dolomite, composed essentially of small rounded quartz grains with interspersed pebbles up to one-half inch in diameter. In the outcrops and cliff exposures the rock is severely pitted and seems to have undergone rather effective differential weathering. The composition is radically different from that of the rock which constitutes the crest of the Sable Falls, as may be inferred from the analysis (specimen 57; see Table I). The composition as indicated in the analysis corresponds within very close limits to that which is given for the Hermansville cap rock one eighth of a mile above the crest of Laughing Whitefish Falls, approximately 54 miles to the south and westward.

SHORE ESCARPMENT SOUTH OF GRAND MARAIS

A steep rock escarpment representing the Nipissing shore cliff parallels the highway along the south shore of West Bay near Grand Marais. The rock in the crest of this scarp is exposed along the road about a mile south of the West Bay shore in the center of Section 8, T. 49 N., R. 13 W., and grades from a siliceous dolomite to a dolomitic sandstone. It is light gray, firm and resistant, and fine in texture. It is composed of small spherical to subangular grains of quartz embedded in a matrix cement of dense dolomite. A sample (specimen 53) taken from the highest terrace in the cliff gives by analysis 50.16 per cent of silica and 49.17 per cent of calcium and magnesium oxides and carbon dioxide. Less than a mile north of the crest of the escarpment, or a few hundred rods south of the shore of West Bay, in the NW. $\frac{1}{4}$, SW. $\frac{1}{4}$, Sec. 5, T. 49 N., R. 13 W., Chipmunk Creek, flowing a very thin ribbon of water, breaks over the rock ledge to expose a fairly thick section of sandstone. The rock in this formation is grayish, fine in texture, and loose in structure. It is highly siliceous but weakly cemented; hence it is not especially resistant (specimen 58; see Table I). The stratigraphic position of the sandstone here suggests a strong relationship to the Cambrian formation. The contact with the overlying Hermansville dolomite may be observed upslope toward the crest of the escarpment merely a few rods to the south.

The outcrop of Cambrian sandstone in the shore cliff which

marks the location of Chipmunk Falls is the most easterly exposure of the formation in Alger County. No evidence of rock ledges is found along the shore of Lake Superior in Luce County to the east. The falls of the Tahquamenon River, 38 miles to the east in Luce and Chippewa counties, reveal the next nearest exposure of Cambrian sandstone of any consequence. These falls have been described in a previous paper involving the glacial geology of Luce County.⁹

SUMMARY AND CONCLUSIONS

The numerous geologic features, expressed in the form of falls and rock cliffs along the south shore of Lake Superior in Alger County, are intimately associated with the stratigraphic relationships which exist between the Cambrian sandstone and the Hermansville siliceous dolomite. The sandstone, which is of Cambrian origin, is in the main highly siliceous and consists essentially of subangular to rounded grains of weakly cemented quartz. It is friable and extensively jointed and, consequently, is readily influenced by weathering activities. The Hermansville formation, which forms an unconformable mantle over the sandstone, is younger and undoubtedly belongs to the Ozarkian. It is a firm, relatively hard rock, composed largely of rounded to subangular, frosted grains of quartz embedded in a matrix of dolomitic cement. It is resistant to erosion and has played an important rôle in the geologic development of the escarpment rim which borders the south shore of Lake Superior in Alger County.

Previous to the invasion of Pleistocene glaciation in the Superior basin, the Hermansville formation apparently covered a much more extensive area than at present. This is shown by the presence on Grand Island of isolated outliers which have been preserved from erosional activity. When the Superior lobe advanced through the Superior basin it plowed its way through the then exposed Hermansville formation and gouged deeply into the underlying Cambrian sandstone. Upon retirement of the ice sheet the basin became occupied with waters which in the early development, through the Algonquin and Nipissing stages, stood at decidedly higher levels than does the modern lake.

During the stages of higher lake levels the water in the basin

⁹ Bergquist, S. G., "Surface Geology of Luce County, Michigan," *Pap. Mich. Acad. Sci., Arts and Letters*, 14 (1930): 438-444. 1931.

pounded with tremendous force against the face of the rock cliffs. The soft, friable Cambrian sandstone was effectually undercut by wave activity to develop overhanging ledges in the more resistant Hermansville dolomite. The projecting rock cornices were thus left unsupported, and through the influence of penetrating joints were dropped, block by block, to the base of the cliff, where further erosion reduced them to transportable débris. In this manner the cliffs were forced in many places to retreat landward, but the rate of recession was controlled largely by the cover of resistant rock.

When the water level in the Superior basin was depressed as a consequence of the opening up of new and lower outlets, the present lake stage was initiated. The waters retreated from the older shores and in places left the rock cliffs somewhat removed from wave action. At present, except where the cliffs flank the immediate shore, as in the Pictured Rocks section, east of Munising, erosional activity is being accomplished mainly by north-flowing streams and rivers which head in the higher upland areas of the interior. Cliff recession, as linked with modern stream work, is quite localized, and the effects produced are small as compared with the wave work accomplished during Algonquin and Nipissing times. Future recession, if dependent upon stream work and surface erosion alone, will eventually result in the development of deep, narrow gorges in the channels where the falls are slowly retreating upstream.

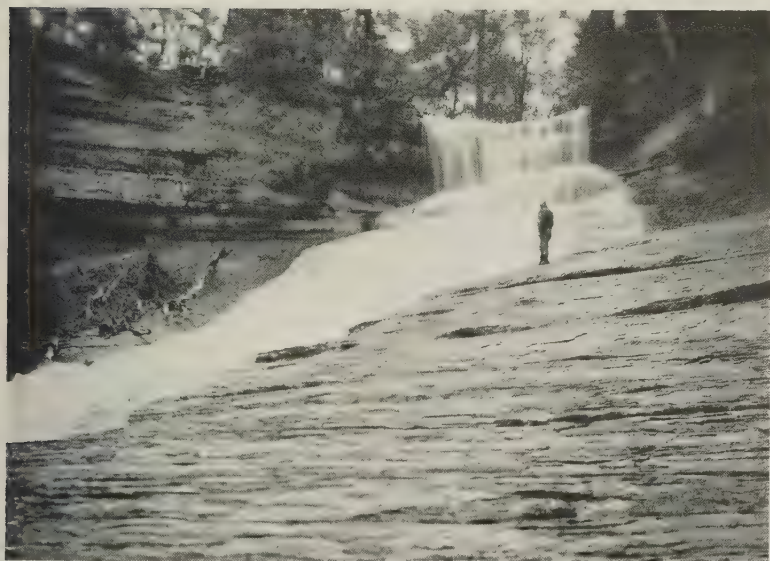
The chemical analyses of the rocks as listed in Table I of this report were prepared in 1930 and 1931 by O. B. Winter, R. J. Davis, Miss F. Lamb, and Miss L. I. Butler, of the Michigan State College Chemistry Experiment Station.

MICHIGAN STATE COLLEGE
EAST LANSING, MICHIGAN

PLATES XLV-LI



FIG. 1



Photographs by L. C. Hulbert

FIG. 2

Laughing Whitefish Falls



Photograph by L. C. Hulbert

FIG. 1. Upper Au Train Falls



Photograph by Michigan Department of Conservation

FIG. 2. Lower Au Train Falls



FIG. 1. Wagner Falls



Photographs by L. C. Hulbert

FIG. 2. Munising Falls

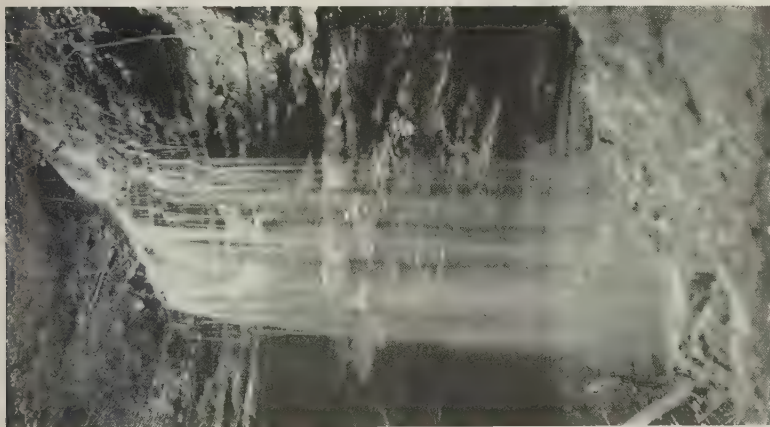


FIG. 1. Tannery Falls



Photographs by L. C. Hulbert

FIG. 2. Base of Tannery Falls (undermined sandstone)

PLATE XLIX



Photograph by Michigan Department of Conservation

FIG. 1. Miner's Falls



Photograph by L. C. Hulbert

FIG. 2. Sable Falls

PLATE L



FIG. 1. Façade of Pictured Rocks



Photographs by Michigan Department of Conservation

FIG. 2. Miner's Castle (view from land)

PLATE LI



Chapel Falls

Photograph by S. G. Bergquist

DUNES OF THE HERRING LAKE EMBAYMENT, MICHIGAN

IRVING D. SCOTT AND KENNETH W. DOW

THE Herring Lake embayment is situated in the western portion of Benzie County, Michigan, approximately six miles south of Frankfort and an equal distance north of the town of Arcadia (Map 40). The depression lies within a prominent U-shaped spur of the Manistee Moraine, which was formed probably during the closing stages of Lake Warren. The spur is open to the west, and the end extends to the shore of Lake Michigan to form steep bluffs 300 feet or more in height.¹ The embayment is occupied by two lakes of moderate size; that farthest east, at an elevation of about 13 feet above Lake Michigan, is known as Upper Herring Lake. This lake drains through Heron Creek into Lower Herring Lake to the west, which, being connected by a short outlet, stands at the same level as Lake Michigan. The purpose of this paper is to trace the geologic history of the depression from its inception to the present time, as evidenced by the physiographic forms now existing in the area. The hinge line, or zero isobase, of the Algonquin beaches runs just to the north of the depression, which, therefore, lies within the area of horizontality.

These studies, carried out during the summers of 1934 and 1935, are illustrated by sketch maps of the dune area made by the junior author. Merely the outlines of the ridges have been shown, which must not be mistaken for contour lines, since the charts are intended solely to show the various forms, with their relative sizes and position. They should not be regarded as accurately scaled maps of the area, but they are believed to be more representative than the incomplete and inaccurate maps available, with the single exception of the United States Lake Survey Coast Chart No. 9, corrected to 1900, which, however, does not include the entire dune area. For

¹ Leverett, F. L., and Taylor, F. B., *U. S. Geol. Surv., Mon.* 53, pp. 303-308; Pl. XXXII. 1915.

convenience in reference, numerals have been assigned to locations of particular importance, ridges, dunes, etc.

Inasmuch as the moraine which surrounds the Herring Lake depression is of Warren age, as already stated, the embayment must have been filled by a tongue from the ice lobe which occupied this part of the Michigan basin during the Warren-Chicago stage of the Glacial Great Lakes.

Subsequent melting completely freed the Michigan basin of ice and initiated the Kirkfield stage of Lake Algonquin, the level of which was considerably below that of the present Lake Michigan (possibly fifty to sixty feet).² Because the depth of the Herring Lake depression is relatively shallow, it is believed to have been dry at this stage. Uplift of the Kirkfield Outlet raised the waters to the three-outlet or main Algonquin stage, twenty-five feet above present Lake Michigan.

With the uncovering of the North Bay Outlet the waters receded to the early stage of Lake Nipissing, which was likewise below the present lake level. At this time the Herring embayment was dry, except for the area occupied by Upper Herring Lake. The uplift of the North Bay Outlet caused a repetition of the Algonquin conditions and resulted in a rise in the level of the Nipissing lakes to the Port Huron Outlet, which at that time was fifteen feet above the Lake Michigan level. Therefore, the embayment was again flooded.

Since Nipissing time the outlet at Port Huron has been cut down fifteen feet, with one possible halt at the Algoma stage. Under present conditions there has been a more or less periodic fluctuation in level amounting to more than five feet.³ Thus we note four dis-



MAP 40. General map showing location of the Herring Lake embayment

² George Stanley, personal communication.

³ Profile of lake levels, United States Lake Survey.

tinct periods or levels (late Algonquin, late Nipissing, Algoma, and present) at which shore adjustments could have been formed and preserved.

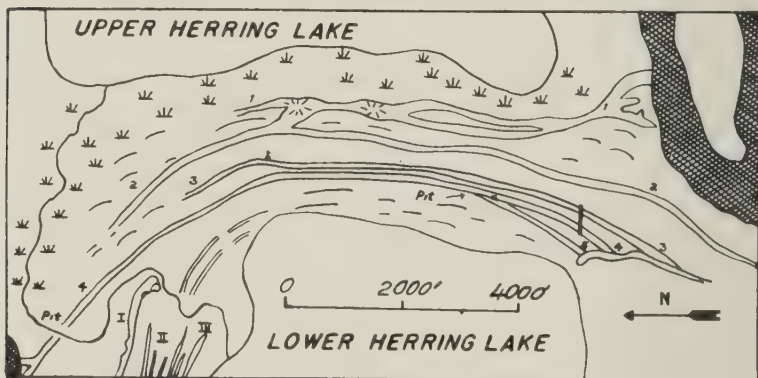
In this résumé it is pointed out that, during the later stages of Lake Algonquin, the Herring Lake embayment consisted of a rather long depression between the moraines, with a broad opening into the large lake, and was flooded. Therefore, one would expect to find evidences of an Algonquin level along the eastern and adjacent shores of present Upper Herring Lake. However, no shore features could be definitely recognized at the locations where this level should exist. The lake is practically surrounded by the moraine, which presents a very uneven front, with numerous indentations and low spurs running out almost to the lake. Evidences of shore activity on the morainic border during Algonquin time could easily have been destroyed in the building of the road which runs around the lake along the edge of the moraine.

It is possible that the main road in front of the W. D. Salsgiver resort on the north side of the lake is located on an Algonquin shore inasmuch as it stands about eleven feet above Upper Herring Lake. This would be approximately correct for the Algonquin level, since the present level of Upper Herring Lake is about thirteen feet above that of Lower Herring. Farther along, to the northeast, the road runs very close to the lake on top of the moraine, a spur of which juts out at this point and has been truncated by the waves. Along the exposed face of the morainic bluff is a poorly developed bench about ten feet above the Upper Herring Lake level, which, again, may represent the Algonquin level. From these meager shore features it seems evident that the wave activity in the bay head was very slight during this time.

To the west, separating Upper from Lower Herring Lake, is a rather wide strip of ground consisting of an interesting series of ridges separated by shallow troughs (Map 41). These features are roughly parallel and are oriented in a general north south direction. They are all curved, with their concave sides toward the west, indicating activity from the main lake. With the exception of the easternmost these ridges have smooth, gentle slopes and are composed of coarse, well-rounded fragments.

The first, or easternmost, ridge starts from the moraine to the south and continues in a northerly direction about halfway across

the depression before it dies out. Although there are many variations in height, it is a well-defined ridge throughout its extent; it drops away sharply to the low swampy area at the east. To the



MAP 41. Series of mid-bay bars between Upper and Lower Herring lakes

south it is low and branches to join the moraine. Continuing north these forks or branches merge into one ridge, then divide into two ridges with a low swale between, and eventually merge again. It is composed of sandy material to a depth of at least four feet. The average elevation is eleven feet above Upper Herring Lake, which would place it at about twenty-four feet above Lake Michigan. The crest of the ridge is uneven and in two places rises to twice its usual height. These elevations have steep slopes to the east, approaching the angle of repose. This ridge is interpreted to have been a first unsuccessful attempt at the formation of a mid-bay bar from the south side of the indentation. Its irregularities of contour and surface are due to subsequent modification by wind action, although it is possible that the two highest points may have been islands.

Bar 2 is longer and slightly lower than the sandy ridge first described. It starts as a low ridge farther to the southwest and becomes higher and better defined to the north, where it intersects and merges with an offshoot from Bar 1, and continues for some distance before dying out. To the north and east the land is rolling, with no definite bar arrangement that can be traced. This gently rolling area merges gradually into the swampy tract bordering the creek.

The southern end of Bar 3 is no longer visible, since it and also the ends of Bars 4 and 5 disappear under the long dune ridge farthest back from the shore, which has been blown up over the ends of these bars. Bar 3 runs parallel to Bar 2, but is not quite so long and is somewhat lower. To the north it becomes confused and dies out.

Bar 4 is the only one of the group which is well defined throughout its extent and continues all the way across the embayment, except where it is cut by Heron Creek, to the moraine on the northern side, which it joins in a fork. (It will be recalled that a similar forked or branched effect at the juncture of the bar with the moraine also occurred in the case of Bar 1.) Bar 4, therefore, represents the first completely successful closing off of a portion of the embayment. The top of this bar, which is the highest of the group, is at an elevation of approximately twenty-five feet above Lower Herring Lake. At the time these studies were made the outlet of Lower Herring Lake into Lake Michigan was not dammed, and both lakes stood at about the same level. There is a gravel pit in Bar 4 at the point of junction with Bar 5. The material exposed ranges from sand to gravel to small cobbles about a yard below the surface. It is well stratified and is indicative of strong wave action. The beds are nearly horizontal, but dip gently to the west and southwest. In the northern part of Bar 4 a small pit has been dug, in which the same type of material can be seen. Bar 5, which is lower than Bar 4, is relatively local. It can be traced from the sandy ridge to the south and runs northeast until it joins Bar 4.

The southern parts of Bars 3 and 4 are crossed nearly at right angles by a narrow ridge of earth. This is an artificial grade constructed for the old railroad which was built along the southern shores of the lake during the time of the lumbering operations in this region. It is listed merely that it may not be confused with the bars.

From their material, general appearance, and elevation the last four ridges in the series described above have all the characteristics of mid-bay bars formed during periods of intense wave and current action in the waning stages of Lake Algonquin. They were built up from the south, they differ slightly from one another in height, and are incomplete, with the exception of the fourth bar, which entirely crosses the embayment. In accordance with Johnson's classification⁴ the term "mid-bay bar" is used, since they reduce

⁴ Johnson, D. W., *Shore Processes and Shoreline Development*, pp. 303-304. 1919.

the length of the depression by about one half. These bars probably came into existence because the embayment was so shallow that the waves broke before they had a chance to reach the shore. The depth here, approximately ten feet, would presuppose the existence of waves ten feet high along the Algonquin shore.⁵ This height is not improbable since waves have often been observed on Lake Superior which were accurately determined to be from twenty to twenty-five feet in height.⁶ No measurements of waves on Lake Michigan are known to the writers, but it is believed that they are somewhat near the same magnitude.

This premature breaking of the waves, which resulted in the building up of the bars, accounts for there being little or no evidence of a well-developed Algonquin level along the eastern shores of Upper Herring Lake, and also for the lack of dunes in that area.

After Lake Algonquin the deciphering of the history of the embayment is based upon the interpretation of the dune ridges, and some discussion of the principles involved is here undertaken. The relative age of dunes has been determined by: (1) position or location; (2) extension or direction; (3) development — (a) simple ridges, (b) deformed ridges, (c) size; (4) soil profile. Regarding position or location, the dunes farthest back from the shore were the first to be formed and therefore are the oldest. This principle is based upon the assumption that there has been no dune migration. By "migration" is meant the progression of a dune in response to winds subsequent to its detachment from its place of origin. This assumption is correct for most of the dune areas about Lake Michigan, but should be checked in each instance. "Extension" or "direction" refers to the direction in which the dunes run, which sometimes furnishes a clue to the time and the manner of their formation. The development of a series of simple undeformed ridges which run approximately parallel to one another indicates a prograding condition of the shore, whereas deformed ridges indicate retrograding or oscillating conditions.⁷ On a retrograding shore sand is largely removed by wave and current action. Thus the dunes became deformed without notable additions of material and are therefore

⁵ Johnson, *op. cit.*, pp. 16-18.

⁶ Gaillard, D. D., "Wave Action in Relation to Engineering Structures," *Corps of Engineers U. S. Army, Prof. Pap. 31*, p. 82. 1904.

⁷ Solger, F., *Dünenbuch-Werden und Wandern der Dünen*, pp. 40-45. 1910.

of moderate size. On the other hand, exceptionally large deformed dunes (150-250 feet high) are the result of the alternating addition and abstraction of sand along the shore of a lake whose level oscillates. "Oscillation" in this sense refers to the normal short-period fluctuations such as occur under present conditions. As stated above, dunes of this type are to be expected at the flood stages of both Algonquin and Nipissing, Algoma possibly, and the present.

The work of Scott and of Stevenson⁸ in other portions of the Lake Michigan basin has shown consistently that the largest dunes are of Nipissing age. The apparent chaotic appearance of the dunes is in reality an orderly arrangement. Between the Algonquin and the present Great Lakes the total drop in level was but twenty-five feet, and the several stages persisted long enough for the shore to be cut back to nearly the same locality at each stage. Under these conditions were formed a series of greatly deformed ridges piled up within a narrow zone, the later on the earlier, to heights which rival those of any others so far discovered. These deformed dunes are particularly well represented in the areas south of Frankfort.

In this study soil profiles were utilized sparingly within the area for correlating the dunes with one another as to approximate age. No attempt was made to compare them with the profiles of dunes in other areas, the method employed farther to the south. Owing to differences in climate and degree of leaching, results obtained from the use of this method in this more northern region are not considered reliable except in comparisons within a local area. With this brief discussion in mind the dune area of the depression will be considered.

Along this western side of Michigan the Herring Lake embayment seems to be the only example of two fairly large lakes, distinctly different in age, that occupy the same depression. A great series of dunes have been piled up within the embayment, but none have formed at the bases of the high headlands to the north and south where they come out at right angles to the beach, since it is the material eroded from these exposed morainic ridges that has in large part provided sand for the formation of dunes along the less exposed portions of the shore.

Starting with the group of dunes to the north of Lower Herring

⁸ Stevenson, E. B., "The Dunes of the Manistique Area," *Pap. Mich. Acad. Sci., Arts and Letters*, 14 (1930): 485. 1931.

Lake (Map 42), the first form encountered in front of Bar 4 is a single, relatively low, sandy ridge (I). The upper portion of the soil profile is deep orange, with much ortstein and some podsolization, and is the darkest found in the dunes of this area. The course of Heron Creek has been deflected to the south in order to get around the southern end of this dune ridge, which stops abruptly at the



MAP 42. Dune area north of Lower Herring Lake

creek and does not continue beyond that point. At the southern end the ridge has been deformed somewhat by the wind, but continues in a general northwest direction until it disappears under the main dune complex. Beyond this point it cannot be traced.

Because of its distinctive soil profile it is considered to be the oldest dune form found, and the location in front of Bar 4 would indicate that it belonged to very late Algonquin time. It may represent a foredune ridge imperfectly developed before, or as, the water level receded to that of the early Nipissing stage. It is the only ridge in this area that may be said to belong to the transition between late Algonquin and early Nipissing.

Between the ridge described above and the shore of Lower Herring Lake are a series of several rather discontinuous, low sandy ridges or bars (II), two of which also seem to continue south of the creek. These indistinct ridges are lower than either the Algonquin or the Nipissing levels and may be interpreted as offshore features of an age contemporary with that of the dune ridge (I).

During early Nipissing the area now occupied by Lower Herring Lake must have been practically dry, except for Heron Creek, with a greater western extent than at present. However, with the return of the waters to a higher level at the Port Huron Outlet, shore activity in this locality was renewed and resulted in the formation of a great series of dunes.

In front of the group of ridges just described (I, II) is a ridge (III) that starts near the creek, travels northwest, and then curves back to the north and slightly northeast and joins with a ridge (IVA) that goes northeast and disappears under the higher portion of the main dune complex. However, it reappears (IVB) farther on and continues in a long curve. Ridge III is approximately fifteen feet above Lower Herring Lake. Inasmuch as this is a dune and not a bar, the elevation of the crest does not represent the Nipissing level, although the ridge itself would seem to be of that age, having been formed after the readvance of the water level. This conclusion is reached partly from the location of the ridge and also because the soil profile is distinctly lighter than that of Ridge I, and is free from ortstein.

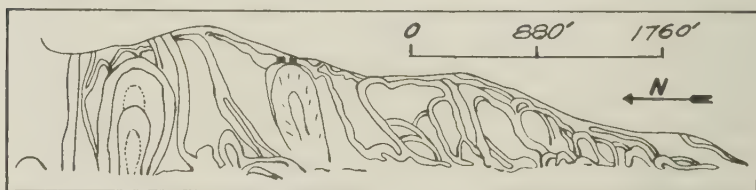
To the northeast of this ridge are morainic hills and spurs, some of which contain much sandy material, but also quantities of rather large boulders, so that there is little danger of confusing any of these hills with the dune ridges in this particular location, a few of which appear to have been blown up or perched upon the gently sloping flanks of the moraine. The series of seven roughly parallel ridges to the north are entirely morainic.

Ridge IVB and the series of lower dune ridges farthest back from the shore to the north and east seem, on the basis of their position, soil profiles, and deformation, to have been formed during the Port Huron Outlet stage of Lake Nipissing. With their formation along the front of the moraine the opening of the depression toward the lake was greatly narrowed.

To the south, in front of Ridge III, running in a general east-west direction, are two sand ridges (V), one of which merges at its eastern extremity with Ridge III. They are slightly lower, and must have been formed subsequent to Ridge III. That these two ridges were formed when the depression was open on the Lake Michigan side and before the existence of the wide bay-mouth bar enclosing Lower Herring Lake is shown by the fact that at their western ends

they merge and curve to the north before they disappear under the deformed dunes, instead of curving south toward the bay-mouth bar, as they would have done if they had been ridges formed along the shores of the present Lower Herring Lake.

Obviously, the high ridges (VI) in this northern area were blown up at a somewhat later date than those farthest from the shore, since the highest of the group buries a portion of Ridge IV. These high dunes are probably of late Nipissing age, although most of them have a surface coating of modern material. All the lower ridges to the west of this series of high dunes are thought to be post-Nipissing.



MAP 43. Dunes on bay-mouth bar north of outlet

It seems probable that the bay-mouth bar came into existence at, or immediately following, the end of the Nipissing. The entrance to the embayment must have been closed when the deformed ridges (VII) nearer the shore were formed, since their soil profile is very similar to the soil profile of the sand out on the northern part of the bay-mouth bar, indicating that this group of dunes must all be of very nearly the same age. They may possibly belong to the Algoma (?). It will be noted that some of the dunes in this series cover the western ends of the little ridges (V) previously described.

The dunes nearest the shore are modern (VIII), and there is one large, recent, compound horseshoe blow that extends back a considerable distance. With the exception of this and several minor blows the entire area is quite thickly covered with second-growth timber, and the dunes are fixed in character.

The dunes out on the bay-mouth bar north of the outlet (Map 43; Pl. LII, Fig. 1) are probably all modern, although parts of them may be of Algoma (?) age. By "modern" it is not meant necessarily that they have been blown up within the past hundred years or so, but that they have formed at some time since the withdrawal of the Nipissing Great Lakes. The soil profile of these dunes is not that

of the light-colored sand such as is found on the beach today, but is of a moderately yellow shade, verging on an orange-brown color.

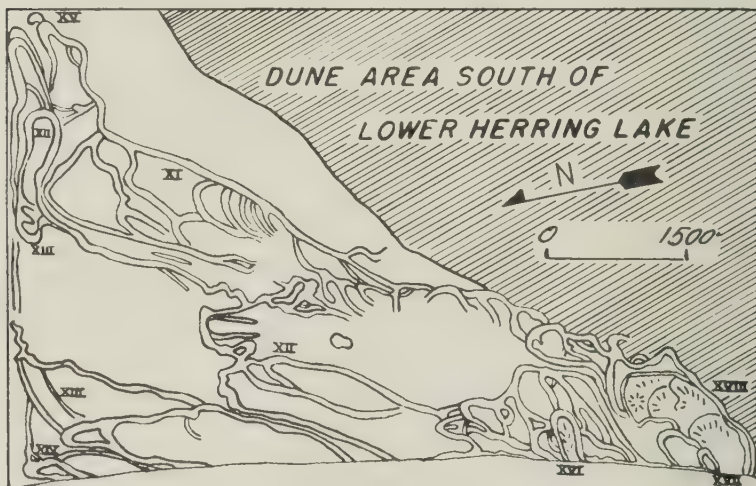
In the northern part of this bay-mouth bar the back slopes of some of the series of horseshoe dunes (IX) have been truncated, and are still in the process of being worn away by the action of the waves in Lower Herring Lake. These are good examples of longitudinal dunes in a humid region, formed on a bay-mouth bar.

In the northwest corner of the lake is a small lagoon (X) separated from it by a low bar approximately six and one-half feet in height. The bar was formed by Lower Herring Lake after the formation of the bay-mouth bar, since it curves to the south to join the bay-mouth bar. This little bar may be composed of material from the truncated dunes to the west. However, since it is slightly higher in the eastern portion, it may have been built down from the east, although the eastern shore of the lake is quite pebbly, and it does not seem as though there would have been available much fine material which could have been carried by the waves. Also, Heron Creek does not set up any strong current in Lower Herring Lake. The crest of the bar is above any known historical level of the lake and might be correlated with the Algoma (?). However, it seems doubtful whether such a transitory form as a shallow lagoon would persist from that time until the present day, even though the bar is so much lower at the western end that a rise of approximately four and one-half feet in lake level would have kept the lagoon filled with water. Because of this conflicting evidence the age of the bar has not been definitely determined other than to say that it is post-Nipissing.

Of the dunes to the south of the depression (Pl. LII, Fig. 2) it is difficult to determine their age accurately, since the geologic record is not so clearly portrayed here as on the northern side, where the bars and other key features are well preserved.

For the most part the dune pattern is complex (Map 44), but is characterized, unlike the section to the north, by long festoon ridges somewhat parallel to the present shore of Lake Michigan, though angling in toward the embayment; and by small horseshoes and apices blown up upon these ridges. These horseshoes are oriented with a general northeast-southwest tendency, indicating an effective southwest wind, a rather noteworthy orientation. As for the long ridges, they have a more easterly trend than does the present shore

line and therefore are beveled at their southern ends, which precludes a definite determination of their age. One must therefore rely upon the soil profiles and the character of the ridges in comparison with the dunes of other parts of the area, for a rather inconclu-



MAP 44. Dune area south of Lower Herring Lake

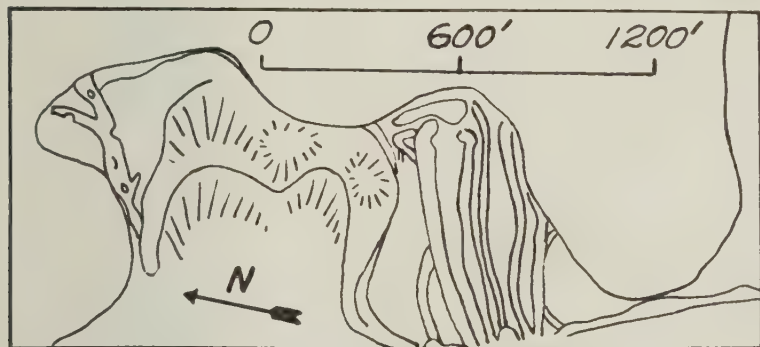
sive correlation. In general, the appearance of these dunes is quite different from those to the north, and the ridges are not so high. Those in the far southern part of the area owe their apparent great elevation to the fact that they are perched on the moraine, which at this point is over 300 feet in height.⁹

The series farthest to the east (XI) have a rather dark profile, with much ortstein and podsolization, and inasmuch as they cover the ends of Algonquin Bars 3, 4, and 5 they are considered tentatively to have been formed during the Nipissing.

The age of those nearer the shore, including the ones along the shore of the present Lower Herring Lake (XII), is not known, except that they must be somewhat younger. As for the latter series, the curving effect of most of the ridges (XIII) away from the south bar would indicate that they were formed previous to the existence of

⁹ Fuller, G. D., "Some Perched Dunes of Northern Lake Michigan and Their Vegetation," *Trans. Ill. State Acad. Sci.*, 11: 111-112. 1918.

Herring Lake. However, the small group (XIV) nearest Lake Michigan has a soil profile identical with that of the dunes on the southern part of the bay-mouth bar, and was connected with them at one time, before the ridge was cut away to give ready access to a large



MAP 45. Dunes on bay-mouth bar south of outlet

dock on the shore, the remains of which may still be seen. The dunes of the southern part of the bay-mouth bar (Map 45) are mainly longitudinal and fragmentary, with the exception of a large active amphitheater blow which rises to a height of eighty feet and whose back slopes are being truncated by Herring Lake.

The old lumber town of Watervale stretches along the southern shore of Lower Herring Lake, and consequently the elevations of the low ridges near the shore cannot be relied upon, since they must have been greatly modified.

To the east there is a question whether or not the old ridge farthest back from the shore ever joined with the series along the small lake. An old logging road runs through the place (XV) where the juncture of the ridges could have occurred. However, from the general appearance of the place it does not seem as though the ridge could ever have been very high at this point, and the loggers probably found it convenient to use this low spot in the ridge as an entrance for their road. If such was the case, it would bear out the theory advanced, that the dunes along the south shore of Herring Lake were formed somewhat later than those composing the series under which the Algonquin bars disappear.

As to the age of the perched dunes to the south, it is difficult to say much. Their foundations are undoubtedly of Nipissing age, but a great amount of more recent material has been piled up on top of them. There are two modern blows, known as "Razor Back" (XVI), at a height of approximately 127 feet, and "Baldy" (XVII), at 330 feet (Pl. LII, Fig. 2). The openings of both are oriented N. 60° E. The ridge forming the south arm of "Baldy" (XVIII), which is now being actively cut into by the wind, displays a foundation of medium yellow sand capped with a mantle of lighter-colored sand, indicating that there were two distinct periods in the building up of this ridge.

In conclusion, it may be added that a well-developed foredune ridge stretches across the entire embayment, but ends abruptly at the morainic ridges where they come out to the shore.

SUMMARY

The Herring Lake embayment lies within a U-shaped moraine open to the west.

The embayment was first occupied by water in late Lake Algonquin time, during which stage Upper Herring Lake was isolated by a series of mid-bay bars. Dune formation during this stage is represented by a single ridge on the north side of the embayment.

The embayment, except for Upper Herring Lake, was drained during the early stage of Lake Nipissing.

At the time of late Lake Nipissing the embayment was again flooded and remained open to Lake Michigan. During this stage not only the series of low dune ridges along the northern shore of Lower Herring Lake, but also the largest parabolic dunes of the area were formed.

The embayment was finally closed by the present bay-mouth bar in post-Nipissing time. Upon this bar and adjoining shores lower dunes of recent origin have formed.

UNIVERSITY OF MICHIGAN

PLATE LII



FIG. 1. View looking south, showing Lower Herring Lake to left, truncated dunes on north bay-mouth bar, Lake Michigan to right, and small lagoon in center foreground



FIG. 2. View looking north from "Baldy," showing Lower Herring Lake to right, southern dune area, and Lake Michigan to left

THE JUSTICES OF THE PEACE AND THE ROYAL PREROGATIVE IN THE REIGN OF JAMES I *

EGBERT R. ISBELL

MUCH has been written about the English justice of the peace — his origins, his function in the local government, his general history. Scant attention has been paid, however, to his position in relation to the central government. Such an inquiry becomes particularly interesting in a period when the contest between the prerogative government and the common law was brought into the open, and the claims of the King were pressed with the utmost vigor. For the peace magistracy hung somewhere between the opposing forces; its roots lay deeply embedded in the common law, yet it was also an instrument of the Crown. Furthermore, as the chief office in the local government, it was in a strategic position to help or to hinder prerogative activities, especially in matters of finance. So constituted, and with such power, the justices of the peace could not take a neutral position, nor could the King look upon them with indifference. What efforts were made by the prerogative govern-

* List of publications referred to by surnames of authors and by abbreviations:

A.P.C = *Acts of the Privy Council of England*.

Hamilton = A. H. A. Hamilton, *Quarter Sessions from Queen Elizabeth to Queen Anne* (London, 1878).

Hawarde = John Hawarde, *Les Reportes des cases in Camera Stellata, 1593-1609* (1894).

Holdsworth = W. S. Holdsworth, *A History of English Law* (London, 1924).

Hudson = William Hudson, *A Treatise on the Court of Star-Chamber in 2 Collectanea Juridica* (1792).

N.R.Q.S. = *North Riding Record Society, Quarter Sessions Records*, edited by J. C. Atkinson.

Reid = R. R. Reid, *The King's Council in the North* (1921).

Somerset Q. S. = *Quarter Sessions Records for the County of Somerset* (Somerset Record Society, Vol. 23).

S. P. Dom. = *Calendar of State Papers, Domestic Series, of the Reign of James I.*

W. R. Rolls = *West Riding Sessions Rolls*. Yorkshire Archaeological and Topographical Association, *Record Series*, Vol. 3 (1888).

ment under James to control these local officers, and the degree of success achieved, will be the subject of the present discussion.

It has been asserted by Beard that the Privy Council of the sixteenth century gained a high degree of control over the justices of the peace; that it communicated with them continually in regard to every phase of local administration, used its power to dismiss them from the Commission of the Peace freely, and, in practice as well as in theory, stood always ready to interfere in matters of either administrative or judicial nature.¹ If this was true of the sixteenth-century Council, it must follow that it was even more true of the Council under such a monarch as James I, who not only developed a theory of divine right, but undertook to make it work. Holdsworth, while admitting the great power of the Council in matters of local government, asserts that in fact its coercive power in the early seventeenth century was weak. He points out that the institution of the peace magistracy derived from a time when the supremacy of the common law was unquestioned; that the powers and the duties of the justices were determined chiefly by statutes and rules of the common law, that the justices acted through common law judicial forms, were accustomed to exercising initiative, were not afraid of dismissal since the office was unpaid, and were subject to the supervision of the common law courts.² Hence, one should expect them to assert a degree of independence of the royal claims.³ He states explicitly that the growing opposition to the King of the officials of the local government was of prime importance in overthrowing the prerogative claims.⁴ But in seeking evidence of this local opposition Holdsworth looks primarily to Parliament, treating that body as a mirror reflecting the sentiments of the local officials;⁵ he does not look for much outspoken opposi-

¹ Beard, Charles, "The Office of Justice of the Peace in England in Its Origin and Development," *Studies in History, Economics, and Public Law* (Columbia University) 20, No. 1 (1904): 118-121.

² See Holdsworth, 6: 58-62.

³ "It is clear that authorities of this kind, thus controlled, will not easily become the mere officials of the central authority, nor easily subjected to a system of administrative law." Holdsworth, 4: 188.

⁴ "In fact these characteristics of the local government, which were fatal to the success of a scheme of royal absolutism, were perhaps the most important cause for the ultimate success of the Parliamentary opposition." Holdsworth, 6: 61.

⁵ Holdsworth, 6: 61.

tion on the part of the justices themselves.⁶ He suggests, in fact, that only at one point did they break away from their habit of obedience, and this was when the King sought to raise money without Parliamentary sanction.⁷ We shall see that they offered much more resistance than has been recognized, and that they were much bolder about it than they have been given credit for.

THE PREROGATIVE AMBITION

Let us first, however, consider the degree of control that the prerogative government assumed over the justices of the peace. For when the local resistance is set against the background of prerogative pretensions, its degree and significance become clearer.

As for the Star Chamber, the justices were liable to be brought before it on charges of negligence or corruption,⁸ or of exceeding their authority,⁹ and the punishments imposed by this powerful body were notoriously heavy.¹⁰ To this must be added the fact that the Star Chamber issued more or less detailed regulations and orders to be executed by the local justices. This was done through the charge which was given twice a year before each setting forth of the judges of assize by the president of the Star Chamber (the Lord Chancellor or the Lord Keeper) to all judges of assize and all justices of the peace who were in the vicinity. The charge was delivered in open court, with all the judges present just as on days

⁶ "Thus in all matters of routine the old habits of subordination and obedience prevailed; and it might be thought that these habits would prevent disobedience or resistance to any orders which might be issued." Holdsworth, 6 : 62.

⁷ Holdsworth, 6 : 62-65.

⁸ "But corruption of officers, or neglect of justices of peace in their duties, in not bringing felons and offenders to punishment, or not certifying recognizances, or not granting the peace, hath had always its due examination and proofs here." Hudson, p. 64. See also p. 109. The court could alter fines set by the justices. Hudson says (p. 118): "And so also fines set by any justices of peace for any riot or force, are no obstacle to the high power of this court, but in their discretion they may either fine it, or add some exemplary punishment unto it."

⁹ The court laid down the following rule in 1598: "Ruled by the Court, that if any Judge, Justice, officer or subject of the realm shall go beyond his bounds and limits, and misdemean himself in any manner, this Court has power and authority to examine and punish this; and this is clear law without any doubt or question." Hawarde, p. 98.

¹⁰ While some of the fines imposed were as small as £5, the more frequent amounts ranged from £20 to £1,000. In addition, other punishments, such as whipping, the pillory, and imprisonment, were frequently imposed. See instances in Hawarde, pp. 49 (1596), 108 (1600), 234 (1605), 264 (1606), 312 (1606), 330 (1607), 334 at 336 (1607).

when cases were brought up for trial.¹¹ So far as the justices of the peace were concerned, these charges dealt with such matters as the residence of justices in London and other urban centers instead of on their estates,¹² the regulation of the distribution and sale of grains,¹³ the suppression of recusancy,¹⁴ attendance at Quarter Sessions,¹⁵ the suppression of rogues and vagabonds,¹⁶ etc.

Turning to the Privy Council, we find that it exercised the broadest sort of jurisdiction over the justices. As will appear later, the Council issued many orders concerning the granting of pensions to disabled war veterans and the raising of money and supplies for royal needs. Equally prolific were orders, among others, for regulating economic practices,¹⁷ for the relief of the poor,¹⁸ the regula-

¹¹ See Hawarde, pp. 20, 56-58. Hudson, in speaking of what he terms the "public causes" looked after by the court, lists among other things the charge given to the judges of assize and the justices of the peace by the Chancellor. He says (p. 53): "And it is usually known that the justices of assize and justices of peace at this day repair thither to hear their charge, how they shall apply themselves in the government of the Commonwealth, when they shall carry an hard hand in the execution of some laws, and when they shall *remittere habemus*."

Hudson mentions (*ibid.*) that during the reign of Henry VIII ("when, I suppose, they were few in number") the justices of the peace of all the counties were required to come to the Star Chamber to take their oath.

¹² See Hawarde, pp. 56, 102, 106, 187, 326, 368; also *S. P. Dom.*, 1615, p. 337; 1619-23, pp. 470, 472; 1623, pp. 497, 508, 592. Though the tone and the frequent repetitions of the command to the justices of the peace to return to their country estates show a determined effort on the part of the justices to evade the order, it was finally quite successfully enforced with regard to London. See *S. P. Dom.*, 1619-23, pp. 467, 469; 1623, pp. 484, 588. In 1617 the Privy Council excused its laxity in enforcing the restriction on the ground that to do so at that time might interfere with the loan which the King was attempting to secure from London. *A.P.C.*, 1616-17, p. 217.

¹³ Hawarde, pp. 20 (1595), 57 (1596), 367, 369 (1608).

¹⁴ *Ibid.*, pp. 264 (1605-6), 300 (1606), 326 (1607).

¹⁵ *Ibid.*, p. 368 (1608).

¹⁶ *Ibid.*, pp. 21 (1595), 57 (1596), 264 (1605-6), 300 (1606).

¹⁷ Orders in furtherance of the duties of the King's alnager and collector of the subsidy: *A.P.C.*, 1613-14, pp. 380-381 (1613-14), 470 (1614); 1615-16, pp. 104, 343 (1615), 588, 672 (1616); 1621-23, pp. 143-144 (1621-22), 313, 382-383 (1622). Orders regulating various aspects of the cloth industry: *A.P.C.*, 1601-4, pp. 347-348 (1601); 1613-14, pp. 51-53 (1613); 1615-16, pp. 68-69 (1614-15); p. 238 (1615); pp. 464-465 (1616); pp. 642-643, 644, 669-671 (1616); 1616-17, pp. 6, 24 (1616); pp. 1-2, 2-3, 20-21, 28-29 (1616); pp. 49 (1616), 252-253 (1617); 1621-23, pp. 131-133 (1621-22), 190-191, 201-202 (1622), 392 (1622-23); p. 200 (1622); pp. 243-244, 263-264, 300-301 (1622), 447 (1622-23); pp. 295-296 (1622), 455-456, 456 (1623). Orders in respect to labor troubles: *A.P.C.*, 1621-23, pp. 214-215, 224-225, 371-372 (1622). Assistance to bankrupt clothiers: *A.P.C.*, 1621-23, pp. 277-278, 313-314, 381-382 (1622), 463-464 (1623).

¹⁸ In addition to a multitude of orders for the conservation, importation, and

tion of brewers and vendors of ale and beer,¹⁹ and for the suppression of rogues and vagabonds.²⁰ Furthermore, the Council influenced the selection of those who were placed in the Commission of the Peace,²¹ and could recommend removal from the Commission.²²

Most of the foregoing regulations, however, numerous and specific as they were, could yet be justified on the ground that they pertained to the general welfare of the realm. And the fact that the Council rarely exercised its power to secure the removal of justices from the Commission would not appear to support an assertion that the prerogative government in the form of the Privy Council sought to bring the institution of the justice of the peace under its complete domination. But it must be remembered that this institution was firmly rooted in the common law; hence any tampering must be done with the utmost caution. The common law aspect of the office lay in these facts: that the local justice derived his powers and duties from the common law as well as from statutes; that he performed his duties according to the judicial procedure of the common law;²³ and that he was subject to the supervision

equitable distribution of grains, and the orders that we have already noted for the relief of disabled war veterans, the Council responded to petitions from destitute individuals and from towns that had been stricken with fire or flood. Relief to individuals: *A.P.C.*, 1613-14, p. 503 (1614); 1615-16, pp. 33 (1614-15), 295-296 (1615); 1621-23, p. 384 (1622). Relief to towns: *A.P.C.*, 1613-14, pp. 265-267 (1613); 1615-16, pp. 204-205 (1615). See also items concerning encouragement of the erection of houses of correction: *A.P.C.*, 1613-14, pp. 597-598 (1614); 1601-4, pp. 507-508 (1603-4); 1613-14, pp. 661-662 (1614).

¹⁹ Restrictions on the brewers: *A.P.C.*, 1613-14, pp. 397, 587 (1614); 1615-16, pp. 50-51 (1614-15), 82-83 (1615). Restrictions on the vendors: *A.P.C.*, 1616-17, p. 308 (1617); 1621-23, pp. 337-338, 373 (1622), 394-395 (1622-23). See also the following items concerning restrictions on the number of alehouses: *A.P.C.*, 1613-14, p. 601 (1614); 1615-16, pp. 179-180 (1615); 1616-17, p. 308 (1617).

²⁰ *A.P.C.*, 1601-4, pp. 27-28, 74-75 (1601), 487-488, 491-492 (1602), 492 (1602-3); pp. 501-502 (1603); pp. 503-504 (1603); 1613-14, pp. 392-393 (1613-14); 1615-16, pp. 64-65 (1614-15), 160, 210-212 (1615); pp. 692-694 (1616); 1616-17, pp. 103, 193-194 (1616); pp. 5 (1616), 419-420 (1617); 1621-23, p. 43 (1621); pp. 152-153 (1621-22), 418 (1622-23); *S. P. Dom.*, 1615, p. 281; 1624, p. 175; pp. 286, 305; *Somerset Q. S.*, p. 273 (1620).

²¹ The Council appears to have had a standing committee for the drawing up of lists of those to be recommended for the Commission. *S. P. Dom.*, 1622, p. 454. See also Holdsworth, 4: 83 (dealing with the sixteenth century), where the Council is described as consulting the Bishops for suitable names for the Commission.

²² Removals by the Council were rare, however, during this period. For one of the few instances see *A.P.C.*, 1621-23, p. 52 (1621).

²³ Even in its administrative capacity the court of Quarter Sessions acted

of the common law courts.²⁴ He might take orders from Parliament or from the King, but he carried them out in his own way, according to traditional common law forms, and under the supervision of the common law courts. This very situation, furthermore, had bred in him a certain degree of independence, for he was accustomed to the exercise of a considerable amount of discretion. This arose not only from the fact that he had acquired a degree of judicial discretion, but many of the statutes that imposed administrative duties on him also required that he exercise judgment, such as the power to license alehouse keepers.

If, then, we can find evidence that the prerogative government went out of its way to dictate the conduct of the justices, or to make them subservient to its own peculiar ends, we may suspect that it desired and sought consciously to dominate and make them the pliant tools of the King. We can, indeed, show that the Council, in its eagerness to exert a close supervision over the justices, as-

through the forms of its judicial procedure. Thus, if a parish had failed to keep its highways properly, it would be presented at Quarter Sessions and fined; the failure of a hundred to keep its gaols in repair and good order meant a presentment and fine for the hundred. See discussion in Sidney and Beatrice Webb, *English Local Government, The Parish and the County* (1906), pp. 307-308.

²⁴ The Court of King's Bench had general supervisory power over Quarter Sessions. This was accomplished in the main by the writ of certiorari, which was issuable out of either Chancery or the King's Bench. Holdsworth, 1: 228. This writ demanded that the record of the case be transferred to the higher court, and its result was either the quashing of the proceedings below on an error of form or on insufficiency of matter, or a trial in the court above of the substance of the complaint. If issued out of Chancery, it was removed to the King's Bench by a mittimus. See W. Lambard, *Eirenarcha*, p. 591 (1619). Certiorari would lie at any stage of the proceedings in Quarter Sessions, up to and including judgment. *Ibid.* The writ lay in all cases, even where the particular statute involved gave the justices of the peace express power to hear and determine. To deny the writ the statute concerned in the particular case had to do so explicitly. Richard Burn, *The Justice of the Peace and Parish Officer* (1820), 23d ed., I: 449. In addition to this form of supervision by the King's Bench, statutory provision existed for the regular sending up to that court of certain records of the local court. For example, under a penalty of 40s. for each failure the clerk of the peace must certify to the King's Bench, within a limited time, a true transcript of every attainder, outlawry, and conviction had before any justice of the peace in his county. Lambard, *Eirenarcha*, p. 588. The default of a recognizance of the peace must be certified to Chancery, the King's Bench, or the Exchequer. *Ibid.*, p. 589. And in all those cases where the justices of the peace had power to receive indictments but not to hear and determine them, such indictments must be certified to the King's Bench as a matter of course, without special request. See *ibid.*, p. 587 at 589.

served powers that traditionally belonged to Parliament, and that it made a definite attempt to supervise the justices in the performance of their ordinary duties. The supervision exercised by the Star Chamber was not excessive or markedly unreasonable. The use made by the Privy Council of the justices of the peace in those directions which obviously pertained to the welfare of the realm bore color, at least, of disinterestedness. As much cannot be said, however, concerning the levying of benevolences and loans, and purveyance. Here we find the justices pressed into service in matters peculiarly of interest to the prerogative government and, at times (in the raising of benevolences and loans), directly in opposition to the will of Parliament.

But the desire of the prerogative government to bring the local justices under its complete domination finds most conclusive proof in the relations of the Privy Council to them through the judges of assize. These judges, though of the common law and members of the central courts, also served while on circuit as administrative officers of the Council.²⁵ The Council often wrote letters of instruction to the judges while they were going their rounds, and of these, so far as concerns the justices of the peace, the famous Order of 1605 is outstanding.²⁶ This is entitled: "Orders conceived fit to be put in execution in these several counties of this realm for the better preservation of his Majesty's subjects in peace, order, and obedience within the same." It then proceeds to lay down requirements for the justices of the peace, and institutes a method of minute supervision of the justices through the systematic reporting of their conduct to the King and the Council. These requirements were: First, every justice of the peace within a county must be present at every Quarter Sessions for that county from the beginning to the end. Second, the clerk of the peace must certify to the judges of assize any and all justices who were absent from any sessions or who re-

²⁵ Bacon, in his address to the judges of assize just before their summer circuit in 1617, said: "You must remember, that besides your ordinary administration of justice, you do carry the two glasses or mirrors of the state; for it is your duty in these your visitations to represent to the people the graces and care of the King; and again, upon your return, to present to the King the distastes and griefs of the people." James Spedding, *Letters and Life of Bacon* (1872), 6: 211; quoted in Holdsworth, 1: 272-273. See Holdsworth, 4: 75-76, who describes in some detail the administrative duties of these judges.

²⁶ This order is quoted in full in Hamilton, pp. 67-71; also in J. C. Cox, *Three Centuries of Derbyshire Annals* (1890), 1: 4-6.

maintained during only part of the sessions. Third, the judges of assize must ascertain the reason for such absences or nonattendance, and where there was no adequate excuse, report the offending justice to the Chancellor, who would in turn deliver the report to the King and the Council. Fourth, the judges of assize were, in conference with the justices of the peace, to divide all the counties up into convenient districts, and assign certain justices to be in charge of and responsible for each division. Fifth, the justices of the peace of each of these several divisions within a county were to assemble at some convenient place within the division "near about midtime" between each Quarter Sessions, to inquire of and see to the execution of certain matters, which are listed under item six. Sixth, certain named statutes are to be executed, and the justices are to be informed as to all recusants, murderers, outrages, etc., within the division, and to give special attention to the licensing of alehouses. Seventh, the constables and petty constables and other petty officers within a division must attend these divisional sessions to give information on the matters that the justices were required to look into, and to bring offenders with them. Eighth, the justices of the peace in these divisional sessions must appoint a clerk to keep a record of the meetings. Ninth, this clerk, together with the constables, must certify to the judges of assize at each assizes "upon their oaths what Justices of the Peace were absent from any such assemblies." Tenth, punishment was to be dealt out at these divisional sessions for common offenses such as drunkenness, disorders, idleness. Eleventh, the judges of assize were to report back to the Council concerning the conformity of the justices to these orders. This item bears quoting:

(11) Item, that the Justices of Assizes do at every assize inform themselves as well by the Clerks of the Peace, Constables of the Hundred, as otherwise, what service have been performed by every Justice of the Peace since the assizes last before in apprehending of murderers, robbers, and thieves, in punishment of rogues and vagabonds, in suppressing and putting down of alehouses and tippling houses, and in punishing such other offences and disorders wherewith the country is most infected, and who hath been negligent in doing their duties therein, and to make relation thereof to the Lord Chancellor, and his Lordship thereupon to make it known to his Majesty and his Council aforesaid.

This Order of 1605 has been commented on as of interest because of the fact that it seeks to organize the counties into divisions and to make the justices resident in each division responsible for

that particular area — thus possibly accounting for the origin of the Petty Sessions that were known late in the century.²⁷ But there is no evidence that divisional sessions were actually established pursuant to this Order of 1605. Even if there were such evidence, however, the writer feels that this Order has another and a much greater significance. For it is patently a bold effort to bring the local justices more completely under the power of the prerogative government. In requiring the justices to hold an extra sessions the Council was undertaking to prescribe that which heretofore only Parliament had prescribed. Furthermore, the Council sought to make the justices feel that their every move was subject to its approval; they must attend both these special sessions and every Quarter Sessions or stand ready to show a good reason for their absence — not only must they attend, but they must be present “from the beginning of the same sessions to the end thereof.” Finally, the order concludes with a sweeping command that the judges of assize must inform themselves as to the general conduct of all justices of the peace who have been “negligent in doing their duties . . . , and to make relation thereof to the Lord Chancellor, and his Lordship thereupon to make it known to his Majesty and his Council. . . .”²⁸ Such an assumption of supervisory control exceeded anything that the Council had yet attempted. In its provision for special sessions with limited jurisdiction, the Council sought to accomplish by ordinance that which previously had been regulated only by statute;²⁹ in its program for a constant surveillance and

²⁷ See Hamilton, p. 67; Holdsworth, 4: 147-148.

²⁸ Hamilton, pp. 70-71; see also p. 68 (items 2 and 3).

²⁹ The statute 36 Edward 3, c. 12 (1362), ordained that sessions should be held quarterly. By the statute 12 Richard 2, c. 10 (1388), this provision was repeated, but discretion was given to the justices to meet oftener than four times a year by the inclusion of the words “at the least.” By the statute 2 Henry 5, stat. 1, c. 4 (1414), the provision for Quarter Sessions was repeated, and the power of discretion in the justices as to holding more frequent meetings was reaffirmed by the words, “and more often, if need be.” Because of the great increase in duties which the statutes imposed on the local justices, the sixteenth century witnessed a differentiation of sessions. See Holdsworth, 4: 146. But this was accomplished by statutes. In addition to that of 12 Richard 2, which gave the justices discretion in regard to more frequent meetings, those statutes which imposed new duties often stated whether these duties were to be performed by Quarter Sessions or by a specified number of justices. Provision for the latter, naturally, allowed for the development of special types of sessions. Then there was the statute 5 Elizabeth, c. 4, sec. 11 (1562-63), modified by 1 James 1, c. 6 (1603-4), which provided for a special sessions for the fixing of wage rates. Also,

minute supervision over the activities in general of the local justices, the Council carried the royal prerogative to a new extreme.³⁰

It is obvious that such orders, if effective, would serve to bring the justices of the peace very much under the domination and control of the Privy Council. But the Council's coercive power was weak. First, in dealing with the justices it had to work with a body of officials who were unpaid, and hence were not to be intimidated

the statute 33 Henry 8, c. 10 (1541-42), set up a quarter sessions for each hundred, which was to meet at least six weeks before the county Quarter Sessions. This statute was repealed in 1545 (37 Henry 8, c. 7) as causing too great inconvenience.

Now we find the Privy Council attempting to set up an organization similar to the discredited one of 33 Henry 8 — and without going to the trouble of getting Parliamentary sanction.

³⁰ This is the most striking feature of the Order. Its obvious intent, first expressed in item 2, and repeated in items 3, 9, and 11, is to hold every individual justice strictly accountable to the Privy Council for the proper execution of the general duties of his office.

The history of the relation between the Privy Council and the justices reveals no such close supervision. The exacting nature of the Order reminds one of the Continental system in which, speaking generally, in the development of the modern state, medieval institutions had been discarded and the local officials knew no law and no superior courts, but only the will of the central executive. It is true that from the time, in the early sixteenth century, when the Council became a strong executive body, it issued a multitude of orders to the local justices, both directly and through the judges of assize. But the justices were left free to carry out these orders in their own way, and were accustomed to a degree of discretion. See Holdsworth, 4: 164. Holdsworth remarks, further (*ibid.*): "It is true that in London, and in those parts of England which were subject to the jurisdiction of provincial Councils, the control of the central government was closer; but it never became so close as to render the justices merely its subordinates and agents — a fact which was recognized by the Council itself." Yet such was the obvious import of the Order of 1605. And in its purpose to impose this minute supervision the Council went farther than ever before in its effort to check up on the justices. It had, indeed, followed the practice of encouraging local officials to report the *laches* of their fellow officials. But these requests had been confined to specific matters, and in each case involved the reporting by a superior officer of his inferior or, at most, of a fellow officer. See Holdsworth, 4: 77 and note 5 for instances. In the present order we have, however, an intent to check up on the attendance of the justices and even on the length of their attendance at Quarter Sessions (see items 1, 2, and 3). But more than this, in items 9 and 11 the Council provided that the justices should be watched and reported for any remissness by their inferiors, the constables and the petty constables.

While the Order of 1605 carefully refrained from any interference with the common law procedure of the justices, or from any specific intrusion on the supervisory control of the King's Bench, it was clearly an attempt on the part of the Council to accustom the justice of the peace to obedience to the executive and to mold him into an efficient tool of the royal prerogative.

with threat of dismissal from office. The Council could reprimand and threaten, but it could not enforce. Second, in acting through the judges of assize the Council relied on a body of men who belonged to the central courts. Their training, their profession, and their sympathies were with the common law, and it would be surprising indeed if, acting in an administrative capacity as agents of the prerogative government, they should have permitted themselves to become the tools of royal ambition. For these reasons one would not expect more than a nominal observance of such an order as that of 1605. The evidence supports this conclusion.

The records of Devonshire (which contain the Privy Council Order of 1605) indicate either that the instructions were not carried out or that in the course of a very few years they came to be ignored. In 1609, for example, the justices of that county received a letter from the Privy Council reprimanding them, in a general way, for failure to carry out directions, and in the Lent assizes of 1612 the judges of assize expressly ordered the justices of the peace in each division to meet at least once after every Quarter Sessions, and once before every assizes.³¹ The letter of 1609 requested the justices to select three or four of their number to carry out orders from the Privy Council and to report back to that body as to the measures taken. Such a letter is eloquent evidence that the system sought to be established in 1605 had failed to function.

As for the judges of assize, the order of 1612 in Devonshire indicates that some effort, though dilatory, was made to carry out the will of the Council in respect to the divisional sessions. The judges themselves also infer that they did actually report back to the King when they returned from their circuits. In 1618, in a communication to the justices of the peace of the West Riding of Yorkshire, the judges of assize made their request "because they are thereof to render an accompt to the Kinge."³² And in 1624 the judges, in writing to the justices of the North Riding of Yorkshire concerning the presenting of recusants at the assizes, say that "his Majesty will expect a speciall accompt of the Countries forwardness in that speciall service."³³ But there is also an indication that, if

³¹ Hamilton, pp. 79, 81. See also *N.R.Q.S.*, p. 204 (1610), for a similar order in Yorkshire.

³² See *Record Series* (West Riding Sessions Records, Vol. 2 [1915]), Yorkshire Archaeological Society, 53: 397-399.

³³ *N.R.Q.S.*, 3: 212.

any reports were made to the King, they were of a general nature, and far from satisfactory — at least up through 1615. James I, in a speech delivered to the judges in the Star Chamber in 1616, said:³⁴

You have charges to give to justices of peace, that they doe their dueties when you are absent, as well as present: take an accompt of them, and report their service to me at your returne. . . . I know not whether misunderstanding or slackness bred this, that I had no accompt but in generall, of that I gave you in particular in charge the last yeare: therefore now I charge you againe that at youre next returne, you repaire to my Chancellour, and bring your accompts to him in writing, of those things which in particular I have given you in charge. . . .³⁵

The local justices found "aid and comfort" in the attitude of the judges of assize.

THE BORDER COUNCILS

But the resistance of the justices of the peace was not, as we shall see, confined to a single order of the Privy Council. Let us look first at the situation along the borders, where the royal prerogative was directly represented by the border councils — the Council of the North and the Council of Wales and the Marches.³⁶ As for the justices within the Northern Parts, the preëminence of the Council of the North over them was supported by specific orders from the Privy Council, such as the instructions of 1556, which were issued to the president of the local council empowering the council to take fines and amercements of offenders, including justices who neglected their duties or abused their powers, or to take bond for their appearance before the Star Chamber.³⁷ An order of 1563 gave to the local council jurisdiction over matters which belonged properly to the justices of the peace, directing the council generally to punish breaches of the laws, including all the penal laws and those laws passed in 1563 concerning servants and laborers, relief of the poor,

³⁴ Quoted by Holdsworth, 6: 58 (taken from *Works of James I* [ed. 1616], pp. 562-563).

³⁵ It is probable that James had just begun the practice of giving these semiannual instructions in person to the judges of assize and the justices of the peace assembled in the Star Chamber. At least we know that from 1595 through 1609 the instructions were always given by the Chancellor. See Hawarde, *passim*. The fact that James did take over this duty in person indicates that he felt the need of impressing the judges with the importance of the instructions. The failure of the judges to report in more than general terms in 1615 was very probably a manifestation of a long-established habit, and one of the reasons why the King now gave his personal attention to the matter.

³⁶ See Holdsworth, 1: 502-503.

³⁷ Reid, p. 185. See *W. R. Rolls*, 3: 3.

and vagabonds.³⁸ The justices revolted against the encroachments of the local council, and asserted their independence by disregarding its orders. This became so serious that the Privy Council felt obliged to intervene on behalf of its subordinate, and it called upon the local justices in the name of the King and Queen to declare themselves willing to "redubb" their former "faults," warning them that otherwise they would be called to York to answer.³⁹

But this opposition on the part of the local justices was not to be subdued.⁴⁰ In 1595 an information was exhibited at York against Henery Farrar and John Lacye, two justices of the West Riding who had refused to recognize a supersedeas of the peace issued by the local council.⁴¹ In November of the same year the Thirlethorp case in the North Riding came up before the Council.⁴² This was

³⁸ Reid, p. 190.

³⁹ *Ibid.*, p. 186.

⁴⁰ See Reid, pp. 221-222, where the justices of the West Riding are described as being determined to deny the Council of the North's jurisdiction. This opposition arose primarily from the sheep farmers and the clothiers, owing to the fact that the council, instigated from above, was enforcing statutes against regraters and woolgatherers, and against stretching of cloth and other fraudulent practices in clothmaking. Under the leadership of Sir John Savile, who as a common lawyer had additional motives for opposing the Crown, the justices of the West Riding first attacked the council's authority to grant a supersedeas, and next its authority to execute the penal statutes except by the common law method of inquest and verdict, "a method which would certainly have enabled nearly every clothier to escape punishment for deceit in manufacture" (*ibid.*, p. 221). Miss Reid then points out that, in spite of its factious nature, this opposition found allies in the courts at Westminster, and the question broadened to include not only the jurisdiction of the Council of the North but also "the whole of the prerogative power of the Crown in matters of justice" (*ibid.*, p. 222).

⁴¹ Queen's Attorney in the Northern Parts vs. Henery Farrar and John Lacye (1595), *W. R. Rolls*, 3: 1-15. The Quarter Sessions had assumed jurisdiction over Mallorye, who had been required to take out a recognizance of peace before Raufe Beiston, a justice of the peace, i.e. a bond to keep the peace and to appear at next Sessions. He appeared, and complaints were placed in the hands of a jury. But when the justices required him to be bound to good behavior, he refused, flourishing a supersedeas, secured from the Council of the North, "which was then thoughte as these defendants yete thinke to be no lawfull discharge to the Justyes in there said proceedings" (*ibid.*, p. 10).

⁴² *W. R. Rolls*, 3: 16-22 (1595). Miss Reid asserts that the local justices of the peace were the first to resist the Council of the North as part of the general resistance to the pretensions of the Crown, and that these two cases were the beginning of the contest (see pp. 335-336). Though the justices were punished in both cases, they refused to let the matter rest at that point, and in the following year (1596) they brought a complaint before the Lords of the Privy Council against the Council of the North, charging it with exceeding its power, and specifying the issuance of a supersedeas. The Privy Council decided against the justices. This did not end the resistance, and in 1598 it "directed the Lord President and Council

also a case of refusal by justices sitting in sessions to recognize a *supersedeas* which had been issued by the council. The justices were firm, asserting that they "would eyther be Justices or noe Justices and that they would suffer noe such Crossinge, which if they did they needed kepe noe Sessions";⁴³ and "they thought her majesty's Counsell ought to grant noe supersedias above xii myles distant from Yorke."⁴⁴

The justices of the peace of Yorkshire sought to limit the power of the Council of the North to keep the peace to an area within twelve miles of York, and Sir John Savile, serjeant-at-law, who defended the cause of the local justices as against the Council of the North, even argued to deprive that body altogether of this power. This struggle again brought on the intervention of the Privy Council, but this time it saw fit to advise moderation on the part of the Council of the North.⁴⁵ The contest continued, however. In 1613 the quarrel was taken before the Privy Council at London, where the mayor and aldermen of the city of York presented a series of grievances, all of which were of many years standing.⁴⁶ Sir Robert Cecil found it necessary to conciliate the justices, and transferred back to them most of the administrative powers that they had lost to the local council.⁴⁷ By 1621 the Quarter Sessions took over the administrative duties that had been exercised by the Council of the North, and the judges of assize replaced the council as a medium of communication between the Privy Council and the justices.⁴⁸

The story of the relations between the justices of the peace and the Council of Wales and the Marches contains a similar note of discord, but in this case the quarrel arose from the inclusion in the Marches of four English counties. In addition to the counties of Wales this council had jurisdiction over the four neighboring counties of Gloucester, Hereford, Worcester, and Shropshire. These counties strenuously objected to the jurisdiction of the council. Not only did they assert that they were English counties, and not a part of

to grant writs of *supersedeas* in moderation, that bonds taken by the Justices should be allowed by the Council, and that if a party bound by the Council had previous notice that a warrant was awarded against him by the Justices, the Council should repeal its *supersedeas*." Reid, pp. 336 at 338.

⁴³ *W. R. Rolls*, 3: 16.

⁴⁵ Reid, p. 339.

⁴⁷ *Ibid.*, p. 386.

⁴⁴ *Ibid.*, p. 16 at 21.

⁴⁶ *Ibid.*, p. 328.

⁴⁸ *Ibid.*, p. 236.

the Marches,⁴⁹ but they were also impelled by a variety of excesses and abuses perpetrated by the council to assert their independence.⁵⁰

In this case the question of the King's prerogative became directly involved. James asserted that he had the power to place these counties under the jurisdiction of the local council, regardless of their historical status, and in 1608 he demanded of the Privy Council an answer to the question whether the King by his own prerogative and the statute 34 Henry VIII, c. 25 (1542), could give power to the Lord President and Council to exercise jurisdiction within the four counties. The Privy Council gave the question to the judges for answer, and they argued the matter for six days, including also the question of the legality of the civil jurisdiction of the Council of the North. Coke gave the opinion, but it was never published and it was probably adverse to the Crown.⁵¹

The part played by the local justices in the four counties concerned was one of active and persistent opposition. In 1608 Lord Eure, president of the Council of Wales and the Marches, wrote to Lord Salisbury, then Secretary of State, complaining of the determined opposition of the justices of Herefordshire and Worcestershire to the authority of the council.⁵² In 1610 a com-

⁴⁹ See Edward Coke, *The Fourth Part of the Institutes of the Laws of England* . . . (1797), 7: 242, where six reasons are presented for the proposition that the four counties should not be considered part of the Marches, but ancient shires of the realm of England.

⁵⁰ See C. A. Skeel, *The Council in the Marches of Wales*, pp. 140-141, where seventeen complaints are set forth. Among these were the illegal proceedings of the council; "its interference with the common law Courts; its undue extension of jurisdiction in matters of title, legacies, etc. . . . The sheriffs of the four counties were more plagued with executing the processes of the Court than with those of all the Courts of Westminster, and often found themselves punished for executing illegal orders." But strongest of all were the following arguments: that the four English shires should not be put in a position different from that of others equally remote from the capital; "that the inhabitants ought not be deprived of their ancient right of trial by jury and remedy by attain; that the subject was in perpetual uncertainty as to the tenor of the instructions, which were alterable at the pleasure of the Crown. . . ."

The opposition to the council was led by Sir Herbert Croft, who had been discharged from the Commission of the Peace. In 1607 he interfered in a case before the council, by securing a writ of prohibition from the King's Bench. This resulted in the matter being taken before the Privy Council, which decided also to take under consideration at the same time the question of the jurisdiction of the Council of the North, and it was at this time that James presented his question of prerogative power. See *ibid.*, pp. 137-138.

⁵¹ Holdsworth, 1: 511.

⁵² *S. P. Dom.*, 1608, p. 398. See also pp. 400, 450-451, 466.

munication from Lord Eure to Lord Salisbury, stating that a last assault was being made by the malcontents in Herefordshire against the jurisdiction of the "Court of Wales," again implicated the justices of the peace.⁵³ The grand jury for Herefordshire in 1610 petitioned the justices of the peace of that county against the jurisdiction of the "Court of Wales," entreating them to recommend that the knights of the shire seek redress from the King.⁵⁴ Sir Herbert Croft, a justice of the peace, was one of the most aggressive leaders of the opposition. He was dismissed from the Commission of the Peace,⁵⁵ and even denounced by the King in person before the Privy Council as a prime instigator of the opposition.⁵⁶

The situation in the border counties thus reveals an active and growing opposition not only to the extension of the royal prerogative, but, in certain aspects, to its very existence. And we have seen that the local justices played an outspoken and fearless part in this opposition. But their grievances were aggravated by the conduct of the border councils. The assertiveness of the prerogative was carried to their very doors, and they were fairly goaded into conflict. As for the rest of England, the organs of the prerogative government were at London — for most of the counties they were remote. Here we might expect a minimum of opposition on the part of the local justices. Here we may look for the real test as to whether the justices were by habit obedient to the will of the prerogative, as Holdsworth suggests, were inclined to defend their common law perquisites, or were passively indifferent. Let us turn, then, to the direct relations of the local justices of the peace of the realm with the Privy Council. To make the test valid, we shall limit our attention to those cases in which there might be a difference in interest as between the Privy Council and the justices. So viewed, the cases group themselves under the subjects of pensions, loans and benevolences, purveyance, and general supervision of the justices of the peace by the Privy Council.

DIRECT RELATIONS WITH THE PRIVY COUNCIL

The Pension Cases

The problem of relief for the disabled war veterans was brought frequently to the attention of the Privy Council. The assessing of

⁵³ *S. P. Dom.*, 1610, p. 637.

⁵⁵ Skeel, p. 137.

⁵⁴ *Ibid.*, p. 649. See also Skeel, p. 139.

⁵⁶ *Ibid.*, p. 145. See n. 50, above.

a rate and the granting and paying of pensions were provided for by statute.⁵⁷ Discretion as to the amounts to be paid to an applicant lay with Quarter Sessions, which could also alter the amounts at will. The recipient, to qualify for any relief, must either have been drafted ("prest") into the King's service from the county making the grant or have been born there, and must exhibit a certificate duly signed by his superiors setting forth his injuries and service.

So much dissatisfaction arose, however, from the way in which the justices handled the granting of pensions that petitions direct to the Council by maimed soldiers whose requests for relief had been refused by the Quarter Sessions, or whose pensions were in arrears or had been curtailed or cut off entirely, were at times fairly numerous.⁵⁸ For instance, the pension of William Waughe, of the County Palatine of Durham, was cut off the moment he attempted to work a little at his trade of shoemaking, although he found himself unable to continue working at it.⁵⁹ The pension of Thomas Huntley, of Sussex, was cut off without any reason being given, although it had been paid for twenty years.⁶⁰ John Egleton, of Essex, aged as well as maimed, was constantly put off with the promise that he would

⁵⁷ 43 Elizabeth, c. 3 (1601), continued by 21 James I, c. 28, sec. 1 (1623-24). The statute reads in part as follows (sec. 2): ". . . everie Parishe within this Realme of Englande and Wales, shal be charged to pay weekelie suche a sūme of Money towards the Reliefe of sicke hurte and-maimed Souldiers and Mariners that soe have bene as afore is saide [that have loste their Lymmes and disabled their Bodies in the Defence and Service of her Majestic and the State], or shall loose their Lymes or disable their Bodies, havinge bene prest and in pay for her Majesties Service, as by the Justices of Peace or the more parte of them in their generall Quarter Sessions to be holden in their sev'all Counties next after the Feaste of Easter next . . . soe as no Parishe be rated above the sūme of tenne Pence nor under the sūme of Two Pence weekelie to be paide, and soe as the totall sūme of such Taxacon of the Parishes, in any Countie where their shalbe above Fiftie Parishes, doe not exceed the Rate of Sixe Pence for everie Parishe in the same Countie. . . ." 4 *Statutes of the Realm*, Part 2, p. 966. For London the limits were set at 12d. 36s. It was further provided that the money should be collected by the churchwardens and petty constables, and paid over to the High Constable who, in turn, must pay it over to one or two designated justices of the peace at each Quarter Sessions—said justices to give an accounting as to all monies so received once a year at the Easter Sessions.

⁵⁸ The Acts of the Privy Council contain eighty-one such petitions, some of which joined several applicants. In these records they vary in number from one to seventeen in a year.

⁵⁹ *A.P.C.*, 1616-17, p. 118 (1616-17).

⁶⁰ *Ibid.*, pp. 266-267 (1617).

be granted a pension "when any should become voyde."⁶¹ The pension of Thomas Raunson, of Essex, was withdrawn on the ground that said pension should come from the county as a whole, and not from a particular parish.⁶² When the plea for restoring the pension was renewed in the following year the justices based their refusal on a technicality, asserting that the case did not come exactly within the statute.⁶³ Baldwin Benford, of Warwickshire, was refused a pension because he went voluntarily to war.⁶⁴

These instances suffice to show that the justices were, for the most part, intent on making the pension burden as light as possible, and that they resorted at times to bare technicalities and rigid interpretation of the statute to avoid pensions.⁶⁵

The attitude of the Privy Council was uniformly sympathetic toward the petitioning veterans, and its orders to the Quarter Sessions not only demanded that pensions be paid but frequently included rebuke of the narrow and penurious attitude of the justices.

In these cases, however, the justices appear to have been uniformly immune to conciliar rebuke, and even to conciliar commands. While they did not openly refuse to grant the pensions ordered, they offered a passive resistance which was equally effective. Communications from the Council would go unanswered for years, and the Council would learn that no action had been taken by the justices through the appearance months and even years later of another petition from the war veteran.⁶⁶ For instance, an order of 1601 to the justices of Leicestershire in behalf of Thomas Yates recited that the Council had issued a previous order in the case in 1598, but that the petitioner now comes again. The letter continues: ". . . notwithstandinge our sayde letters you have not taken any order for his releefe, neither have you retourned answere unto us

⁶¹ *A.P.C.*, 1615-16, pp. 662-663 (1616).

⁶² *Ibid.*, 1621-23, pp. 62-63 (1621).

⁶³ *Ibid.*, pp. 192-193 (1622).

⁶⁴ *Ibid.*, 1613-14, pp. 184-185 (1613).

⁶⁵ Of course, the facts of these cases have their source in the petitioner, and are doubtless so presented as to put his case in the most favorable light. As they appear in the Council records, however, they have been accepted by the Council as true, and they form the basis of the Council's orders to the justices. The local records are, with rare exceptions, silent as to these conciliar communications and, indeed, as we shall see, the justices rarely answered them.

⁶⁶ One out of every five instances in the Privy Council records shows failure on the part of Quarter Sessions to observe in any way previous orders of the Council.

of the reasons of your refusall in that behalf. . . ."⁶⁷ In the case of Lieutenant Price, of Radnor County, an order of 1614 states that a previous order had been issued by the Council about a year earlier, but that "Nevertheles the poore man is agayne an importunate suitor unto us for releife, as having recieved no satisfaccion from yow, neyther have yow retourned us anie answer at all of your proceedings heerein. . . ."⁶⁸ A good five months later the petitioner appeared before the Council a third time, the local justices having neither taken any action in the case nor answered the Council's communications.⁶⁹ In the case of Jeremy Evers, of Bedford County, the Council, in 1617, wrote as follows to the local justices:

Having often heretofore written unto yow on the behalfe of this poore man . . . , a maymed soldyer, and borne in that county of Bedford, wee did at last receive your answer about a twelvemoneth since, which for the present did give us good satisfaction, not expecting that wee should againe be troubled with new petitions from the poore man. . . .⁷⁰

And in 1621-22 the Council wrote to the local justices of Westmerland County:

Having by former letters written from this Board recommended unto you this bearer, Anthony Lucas, a poore maimed souldier, for some reliefe to be allowed unto him . . . wee did expect you would have thereupon taken order to that purpose, but forasmuch as the said Lucas is now againe an humble suitor unto us. . . .⁷¹

The patience of the Council was remarkable. Indeed, the tone of the communications to the local justices is exasperatingly mild, for even after years of total neglect on the part of the justices of a conciliar order, during which time not even a reply to the Council had been made, the Council would write in such terms as the following:

. . . he hath informed us that notwithstandinge our sayde letters you have not taken any order for his releefe, neither have you retourned answere unto us of the reasons of your refusall in that behalf, which wee cannot but impute to some default and want of due regard on your parte in neglectinge our said dyrection or satisfinge us by your aunswere as aforesaide, wee have therefore thought good once more to require you either to take order for such releefe to be yelded unto the saide poore marryner as by our former letters was prescribed, or otherwise to certifie us speedly of the causes that do move you to the contrary.⁷²

⁶⁷ *A.P.C.*, 1601-4, pp. 45-46 (1601).

⁶⁸ *Ibid.*, 1613-14, pp. 502-503 (1614).

⁶⁹ *Ibid.*, p. 642 (1614).

⁷⁰ *Ibid.*, 1616-17, p. 396 (1617).

⁷¹ *Ibid.*, 1621-23, pp. 142-143 (1621-22).

⁷² *Ibid.*, 1601-4, pp. 45-46 (1601).

Thus there is evident in the pension cases a widespread and constant resistance to the demands of the Privy Council. The opposition was passive rather than in the nature of open revolt, but it appears to have been nonetheless determined and effective, and it may seem surprising that the Council did not use harsher methods in combatting it.

Loans and Benevolences

The reluctance of Parliament in granting the requests of the King for money resulted, as is known, in a resort to extraparliamentary methods, namely, the imposition of subsidies, benevolences, and loans.⁷³ This was done by the Privy Council acting through the justices of the peace. The justices were instructed to levy these burdens on themselves as well as on others of means (in fact, the justices were supposed to set a good example for the rest). If the justices were inclined to offer resistance to the prerogative government, one would expect to find it here, and such, indeed, was the case. Not only did justices frequently seek to evade the personal burden,⁷⁴ but there was a sullen reluctance to carry the imposition out on others. In 1614, for instance, the Council addressed a letter to the sheriffs and justices of the peace of all the counties of England and Wales concerning a "contribution" recently levied "for the supply of Ireland, for provicion of the Cautionary Townes in Holland and Zealand, and for the furnishing of the Navye." The letters give as additional reasons the dire straits of the King's daughter and her husband, Frederick of the Palatinate, describing the situation on the Continent in detail. The letter closes as follows: "Upon these reasons, and finding it strange that we heare nothing from you, wee have thought good to second our former letters: and therefore

⁷³ Those who contributed to these loans did not expect to be repaid. Holdsworth, 4:104, n. 6. The legality of this method of raising money was put to the test in the Star Chamber in 1614 in a case against Oliver St. John, and was upheld, but in 1628 Coke reversed himself and denounced it to the extent that contributions were demanded against the will of the subject. See *ibid.*, 5:427, n. 4.

⁷⁴ In connection with the subsidy of 1621, for example, Sir Francis Ashbie, one of the commissioners for the subsidy in Middlesex, was ordered to "bee put out of the commissions of the peace and subsidie, in conformitie to an Act of Counsell of the 27th of September 1621, whereby other commissioners were put out of the commissions for the same occasion." The "occasion" was his effort to lessen the imposition which had been placed on him by the other commissioners. *A.P.C.*, 1621-23, p. 59 (1621).

doe pray and require you, as you tender the good of your countrye . . . to imploy your best endeavors for the speedy returne of this contribution. . . .”⁷⁵

The “heare-nothing-from-you” method appears to have been typical of these cases as well as of the pension cases. But it was pursued under the glare of close scrutiny and in the face of a much greater insistence on the part of the central government. So determined was the King to raise the sums requested that at times the passive resistance of the justices became a good equivalent to open opposition. This is particularly true as applied to London, “his Majesty’s Chamber,” where the activities of the local officials were carried on under the very nose of the King in Council.

The records of the Council provide us with a fairly detailed picture of one effort to raise money in London. It was late in 1616, shortly before the King’s departure on his “Northern Progress,” when the Council requested of London that city’s security under its common seal for a “loane of one hundred thousand poundes,” which his Majesty needed “for sundry necessary and urgent occasions.” The security offered was the King’s “owne counter-security under the greate seale of England.” The mayor and aldermen⁷⁶ acquiesced, but they were not satisfied with the guaranty. With a great show of loyalty and submissiveness to the King’s will, they came before the Privy Council with a request for better security. The Council record is so descriptive that it warrants quoting:

This day there came before their Lordships, Thomas Coventry, esquire, Recorder of the city of London, accompanied with fowre other Aldermen, and returned the humble answere of the city to this effect, that they did dutifullly acknowledge his Majesty’s singular goodnesse and favour at all times towards their city, and seeing that they were as much bound unto him, as their predecessors were ever to any of his Majesty’s progenitors, they would bee ashamed to comme short of those that had gone before them, in expressing their loyall and dutifull affections to so gracious a Kinge, and therefore had all *una voce* agreed and resolved to give his Majestie satisfaction in the point of security as hee desired, not any one man denying or holding up a hand to the contrary. Which they did humbly beseech his Majestie to accept in good part, and to the security which it pleased him to offer them under the greate seale, to vouchsafe to add withall his royal word and promise for the cittye’s indempnitey, which they did esteeme farre more than all the greate seales whatsoever.⁷⁷

⁷⁵ *Ibid.*, 1613–14, p. 557 (1614).

⁷⁶ The mayor and the aldermen of London, as of most of the city corporations, were included in the Commission of the Peace.

⁷⁷ *A.P.C.*, 1616–17, p. 122 (1616–17 — Jan. 23).

There is no indication, however, that the request was granted,⁷⁸ and the transaction, begun with such amiable phrases, in time swung into acrimony and threats. The Privy Council at first undertook to direct the operations, and raised £40,000. Then it turned the whole responsibility over to the mayor and aldermen of London,⁷⁹ leaving them to raise the remaining £60,000. From this point on the matter dragged interminably, and the Council became very outspoken in its displeasure. The London officials appear to have raised ultimately another £40,000, but this was their limit. The Council complained that

. . . soe slow is the performance of what was promised as there is wantinge of that summe very neere twenty thousand poundes . . . which wee cannot but impute either to backwardnes and ill affection . . . or to the negligent and indiscreete carriage of the same. For wee have observed in the course of your proceedings that you have either altogether omitted or sparingly handled many of the best citizens, and others of sufficient meanes and ability that were meete to be dealt withall . . . and have fallen upon persons of weake and meane estate . . . which hath raysed much noyse and clamore and produced little or noe performance. . . . Neither may wee omitt to lett you know that wee did not expect when by our former letters wee required you to certify unto us the name of any one or more that should be found refractory or ill affected to be proceeded withall for example to the rest as the cause should require, you would now after soe longe tyme of breathinge and that the busines had ben thus blasted by ill handlinge retourne such multitudes unto us as you doe, or make this Boarde your mynisters to performe that which belongeth unto you. . . .⁸⁰

The letter closed with a threat that, if the remaining sum was not speedily raised, the Council would require the aldermen to make up the deficiency out of their own pockets.

Even these strong words failed to move the mayor and aldermen, however. The last communication that appears in the Council records concerning the loan resorts again to threat, and employs accusation in even stronger terms:

. . . wee have once againe bene mooved, by waie of advice and admonicion, to open your understandings and to lett you knowe that the matter of the loane . . . hath bene handled with negligence, extreame partiallitie, and suche appearance of backwardnes and ill affection, as if wee should take a strict account of your proceedings therein, you were noe waie able to make any satisfactory aunswere.⁸¹

⁷⁸ In a communication dated March 2 of the same year only the great seal is mentioned as security. *A.P.C.*, 1616-17, pp. 172-173 (1616-17).

⁷⁹ *Ibid.*

⁸⁰ *Ibid.*, pp. 256-257 (1617 — May 28).

⁸¹ *Ibid.*, pp. 298-299 (1617 — July 11).

Purveyance

The exercise of the royal prerogative in regard to purveyance was at least as irritating as the direct requests for money, and of far wider incidence. Purveyance, too, was accomplished largely through the justices of the peace. The Board of Green Cloth, whose function it was to provision the Royal Household, made the bulk of the demands. But the Privy Council also was active in this direction. As for the justices, we again witness the old policy of passive resistance to the royal demands. However, perhaps because of accumulated irritation, perhaps because the demands were growing more oppressive,⁸² we find here instances of open revolt.

The records of the North Riding of Yorkshire provide us with a good illustration of the passive resistance method as applied to purveyance. The Quarter Sessions of that district issued an order in 1607 to the effect that the arrearages payable to Mr. Twentyman for wax for his Majesty's provision should be forthwith estreated to date and collected.⁸³ Two years later the same Quarter Sessions, moved at last by letters from the Lord President of the Council of the North in behalf of Captain Henry Wood, a purveyor, ordered that the captain be paid the same amount as his predecessors had received, provided the said captain enter bond at the Quarter Sessions next after Easter to free the North Riding of all other charges while he should be in office.⁸⁴ At another time letters from the Privy Council were required to move the same Quarter Sessions to order that John Twentyman have paid to him according to the same rate as that levied in the West Riding, "and in such manner and upon the same conditions as the W. R. hath compounded with him. . . ." ⁸⁵ In the same year (1613) this Quarter Sessions, in reluctant response to several letters that had been directed to them from the Board of Green Cloth in behalf of John Twentyman, ordered that £15 be estreated and levied within Richmondshire and paid to Sir Timothy Hutton to the use of the said John Twentyman, in discharge of all arrears up to the end of that year, "and in consideration of his charges spent about the same." ⁸⁶ In 1616 an effort was made to impose a purveyance in kind of wax. The Riding

⁸² See F. C. Dietz, *English Public Finance, 1558-1641* (1932), pp. 167-169, for a graphic picture of the financial predicament of the government.

⁸³ *N.R.Q.S.*, 1: 97.

⁸⁵ *Ibid.*, 2: 24 (1613).

⁸⁴ *Ibid.*, 1: 168 (1609).

⁸⁶ *Ibid.*, 2: 34.

resisted, and finally compromised by paying the purveyor's expenses on condition he would never bother them again.⁸⁷

In the last instance mentioned there is a suggestion of open defiance. In certain other parts of the realm all pretense of compliance was cast aside, and the reasons for resisting the royal demands were marshaled and hurled back at the central government. The brewers of London, for example, objected to the necessity of furnishing beer for the King's household without being paid in cash therefor. They prevailed on the mayor and aldermen of that city to remonstrate with the Privy Council. The arguments employed were: first, that a clause existed in the city charter whereby the King was restrained "from making any prisage or purveyance within the cittie of London and libertyes thereof, without consent of the owner and redy payment"; and, second, that the King already owed the London brewers for more than 2,000 barrels of beer.⁸⁸ The Council, in reply, asserted that "his Majestie may lawfullie take beere and all other like provisions by commission for the service of his howse, paying for all thinges so taken redy money, if the price were under forty shillings, and for all that was above xls., giving bills to be payed by the cofferor according to the appraisements,"⁸⁹ but, as to the sum in arrears, ordered the cofferer to make "present satisfaccion of them for all that have ben taken before Michallmas."⁹⁰ Apparently this did not satisfy the brewers, for we find later that some of them were thrown in gaol "by his Majestie's Officers of the Greene Clothe" for refusing to sell beer to the purveyors. Sir Henry Montague, recorder of the city of London, and certain of the aldermen addressed the Council on behalf of the imprisoned brewers, saying that the demand of the purveyors "was contrarie to the charters and liberties of the cyttie of London graunted by his Majestie's Royall predecessors, and confirmed by his Majestie and by sundrie Actes of Parliament, whereof they [the aldermen] did humbly pray their lordships to have a due and favorable regard."⁹¹ This time the question was given to Sir Edward Coke for an opinion, but the Council later reconsidered and requested Coke to refrain from writing an opinion.⁹²

⁸⁷ *N.R.Q.S.*, 2: 125-126.

⁹¹ *Ibid.*, 1615-16, p. 9 (1614-15 — Jan. 8).

⁸⁸ *A.P.C.*, 1613-14, pp. 647-649 (1614 — Dec. 4).

⁸⁹ *Ibid.*, p. 647 at 648 (1614).

⁹² *Ibid.*, p. 17 (1614-15 — Jan. 16).

⁹⁰ *Ibid.*, p. 647 at 649 (1614).

But the London officials were not alone in their open opposition to purveyance. In 1613 the justices of the peace of Dorsetshire resisted the demands of the Privy Council for "the carryage of a certaine proportion of timber by the inhabitantes of that countie out of the Newe Forrest for the use and service of his Majestie's Navie."⁹³ The local justices appear to have used three arguments to support their refusal: first, that the number of loads required was out of proportion to the demands made on other counties; second, the high degree of inconvenience involved, due to the lay of the county both with regard to the forest and the destination for the timber; third, that they had made a composition with the Board of Green Cloth to exempt them from the burden of carriage.⁹⁴ The Council replied to these objections seriatim, complained that "soe longe tyme hath ben spunne out and lost by answeares and excuses," and ordered that the transportation be provided "without further excuse or refusall," but, whereas it seems first to have suggested the hauling of 1,000 loads, it now stipulated 500. A similar resistance was met with in the neighboring county of Wiltes.⁹⁵

In 1621 the Council ran into like difficulty with regard to Berkshire. Five hundred loads of timber for his Majesty's ships had been bought in Hampshire, and the inhabitants of that county had agreed to haul 300 of them. The Council sent a request to the justices of the peace of Berkeshire for the hauling of the remainder, but was met with a refusal on two grounds: first, the timber lay too far within the borders of Hampshire; second, the price offered for the hauling was too low. There is no indication, however, that the Council retreated in this case.⁹⁶

The prerogative government was thus obviously meeting with a determined resistance from the local justices on a wide front. With regard to loans it was the London area that was chiefly affected, yet in spite of the fact that this district was the very habitat of the central government, resistance, while clothed in polite language,

⁹³ *Ibid.*, 1613-14, pp. 118-119 (1613 — July 6).

⁹⁴ *Ibid.*, p. 118 at 119 (1613 — July 6).

⁹⁵ *Ibid.*, p. 118 (1613 — July 6).

⁹⁶ *Ibid.*, 1621-23, p. 33 (1621 — Aug. 8). We have also found a single case in which punishment was actually imposed. In connection with an imposition of a subsidy in 1621 in Middlesex certain justices attempted to evade in part the assessments which as a body they had levied on themselves. The Council called the offenders before it and expelled them from the Commission of the Peace and from any and all other commissions. *Ibid.*, p. 59 (1621).

was strong. Purveyance affected the whole realm. The fact that the local justices refused compliance and even argued their ground openly reveals how bold the spirit of opposition had become.

CONCLUSION

Thus the prerogative government, clearly seeking to dominate the local justices, met not only with a varied and widespread resistance on the part of the justices in those fields where the King and his Council had a customary supervisory rôle, but also with a lack of coöperation from those who were to be its chief instrument in the extension of its authority — the judges of assize. And if we examine the records more closely we find in the conduct of the Privy Council toward the justices a tacit recognition of the helplessness of the prerogative government against this resistance. Such recognition is evidenced in several ways. We have seen, for instance, that, while it could procure the removal of justices from the Commission of the Peace, it did so rarely. We have also witnessed the patience of the Council toward the justices in the pension cases. But even in those matters which the Council considered most urgent, such as the raising of money for the King, the Council, though expressing itself in strong terms, was for the most part content with bare threats.⁹⁷ And in the raising of supplies, the Council not only stooped to argue with the local opposition, but made concessions.⁹⁸

The local justices were not to be swept from their common law moorings.

UNIVERSITY OF MICHIGAN

⁹⁷ We have found one instance in which the Council obviously succeeded in scaring the justices into submission. This arose out of the "gift" which was raised for the King in 1614. The Privy Council gave curt orders to certain specified justices of the peace in at least the counties of Devon, Somerset, Nottingham, and Warwick to appear before the Council on or before the 20th of November of that year, their presence being required "for some occasions which yow shall understand at your coming." Upon their arrival they were thoroughly scared and sent home with a letter justifying the levying of benevolences, and requiring that the money asked for in this instance be raised. See Hamilton, pp. 48-49 (Devon); *A.P.C.*, 1613-14, pp. 611 (1614) (Somerset), 616 (Somerset), 625-626 (Nottingham), 628-631 (Somerset), 632 (Warwick).

⁹⁸ For example, see the Council's letter to the justices of the peace of Dorsetshire. *A.P.C.*, 1613-14, pp. 118-119 (1613). See also *ibid.*, pp. 647-649 (1614). The Council here took great pains to answer the mayor and the aldermen of London, who claimed that the London Charter exempted the London brewers from purveyance of beer. It also ordered that arrearages be paid.

THE FRENCH ELECTION OF 1871

RUDOLPH A. WINNACKER

ON JANUARY 28, 1871, an armistice was signed between the French Government of National Defense at Paris and the recently proclaimed German Empire. According to the terms of this armistice an election was to be held in France to create a National Assembly which was to decide "if the war ought to be continued or on what conditions the peace ought to be made."¹

The next day, January 29, a decree was issued by the government at Paris setting the date of the elections for February 8 and announcing that the elections would be held according to the law of March 15, 1849. This meant that each department would be considered an electoral district, in which representatives were chosen by means of the *scrutin de liste*.² These first instructions were supplemented during the next few days by four decrees. The first of these made the present prefects and subprefects ineligible for office; the second decreased the number of votes necessary for election on account of the war; the third apportioned fifteen deputies to Algeria and the colonies, where elections were to take place as soon as possible; and the fourth annulled Gambetta's decree of January 31, which had declared ineligible all those persons who had been ministers, senators, councillors of state, prefects, or official candidates at any time between December 2, 1851, and September 4, 1870.

The country which was to choose its representatives according to these rules was in a state of anarchy and disorder.³ Twenty-five of the eighty-eight departments were occupied by the enemy. Four hundred and thirty thousand men were prisoners in Germany. Another hundred thousand were interned in Switzerland and Bel-

¹ Article 2 of the Armistice Convention.

² This law and the following decrees can be found in the *Annales de l'Assemblée nationale, tables analytiques, 1871-1876*, pp. 3-18.

³ On the general situation in France see G. Hanotaux, *Histoire de la fondation de la Troisième République* (Paris, 1925), I: 21-28.

gium. An army of over five hundred thousand was temporarily imprisoned in Paris. The government itself was divided. At Paris the responsible officials were ready for peace at any cost, while the delegation at Bordeaux under the leadership of Gambetta prepared to continue the war. Both branches of the government increased the general confusion by sending out conflicting orders.⁴

After more than nineteen years of Napoleonic dictatorship political parties which might have guided the electorate were practically nonexistent. The Bonapartists were disorganized and discredited after the military defeats and the overthrow of the Empire on September 4, 1870. The Republicans, who had taken their places in the government, had been the cause of further defeats and by the *levée en masse* had brought the whole nation into contact with the war. Victory and glory gained by the regular army would have been welcomed by most citizens, but the disturbances and suffering created by a national war had turned a large portion of the French people from indifference to pacifism. Consequently the war enthusiasm of Gambetta and his followers⁵ tended to discredit the whole Republican party, in spite of the fact that a majority of this party saw no ray of hope for victory and desired peace. Furthermore, the Republican campaign was handicapped in its effectiveness by the party's failure to establish an organization outside the great cities of France — a mistake which Gambetta had vainly tried to rectify during his four months in the provinces.⁶

The Royalists were hardly better prepared to win the elections. The Legitimists had followed the order of their leader, the Count of Chambord, to abstain from all public functions and even from voting during the Second Empire, and hence they and their leaders had largely passed out of the public eye. The Orléanists had not been so ascetically inclined during the past eighteen years, but in their opposition to Louis Napoleon they had shifted not only their arguments but also their own beliefs from royalism to liberalism, with the result that the Orléanist princes had few real supporters in the country.

Consequently, on account of the anarchy within the country

⁴ Gambetta did not resign his office until February 6.

⁵ A defense of Gambetta's point of view can be found in A. Zévaès, *Histoire de la Troisième République* (Paris, 1926), pp. 33-34.

⁶ For Gambetta's attempt to combine politics with national defense see the hostile account of H. Dutrait-Crozon, *Gambetta et la défense nationale* (Paris, 1926).

and the disorganized political life, it seems correct to assume that the election of February 8, 1871, was nonpolitical, that the issue before the electorate was solely the one of peace or war.⁷ The nation's verdict on this question was overwhelmingly in favor of peace at any cost.⁸ However, the deputies chosen at this time were called upon to solve another problem of almost equal importance, namely, the character of the future governmental institutions in France. The Republic established on September 4, 1870, had never been approved by the country as a whole, but had been proclaimed by the people of Paris and had continued to exist only in default of any opposition.

It might be true that, in order to solve this institutional problem in accordance with the views of the nation, a new election should have been held, as the Republicans continued to assert during the following years.⁹ The fact remains, however, that the National Assembly assumed constitutional powers, and therefore the real question concerns the degree in which this body of deputies represented the political opinions of France.

In seeking an answer to this problem great difficulties arise concerning the opinions of the deputies as well as those of the nation. The candidates for election were not asked to publish a political platform. They were chosen in each department by various self-appointed local committees. Some of these committees had been formed during the later days of the Empire and claimed the support of the former *Union Libérale* or of the Republican party; others had been created haphazardly for the present occasion and included the so-called leading citizens of the district. Sometimes the candidates selected at these meetings were not consulted. Royalists and Republicans often ran on the same ticket. At Marseille Thiers' name was included in the lists of both the opposing parties. Even the political reputation of the candidates constituted no definite index to their opinions, for most of the conservative Republicans, like

⁷ On this point unanimity reigns among the authors of books on the Third Republic. See, for example, Hanotaux, *op. cit.*, p. 29; Zévaès, *op. cit.*, p. 33; R. Dreyfus, *Monsieur Thiers contre l'Empire, la guerre, et la Commune* (Paris, 1928), p. 257; Marquis de Roux, *Origines et fondation de la Troisième République* (Paris, 1933), p. 83.

⁸ On March 4, 1871, the National Assembly ratified the preliminaries of the peace with Germany by a vote of 546 to 107, with 23 abstentions.

⁹ See Gambetta's speech in the National Assembly on August 31, 1871, and his speech at Angers, April 7, 1872.

Thiers, had a Royalist background.¹⁰ Under these circumstances the only method of determining the political tendencies of the deputies is an analysis of the votes on important questions in the National Assembly from 1871 to 1875.¹¹ A compilation of this nature reveals that the Assembly elected in 1871 included 389 conservatives from the Legitimist, Orléanist, and Bonapartist parties; 13 deputies who were Royalists in 1873 but who accepted the Republic in 1875; and 336 Republicans.¹² Consequently, the usual statistics for the National Assembly, giving the Royalists 400 dep-

¹⁰ No detailed investigation of this election has been published, but indications of the methods employed appear in some of the memoirs of this period by the Vicomte de Meaux, *Souvenirs politiques* (Paris, 1903); Duc de Broglie, "Souvenirs," *Revue des deux mondes*, Pér. VII, 49 (1929): 543-567; M. de Marcère, *L'Assemblée nationale de 1871* (Paris, 1904); Ch. Chesnelong, *Les Derniers Jours de l'Empire et le gouvernement de M. Thiers* (Paris, 1932); see also Ch. d'Espinay de Briort, "Une Correspondance inédite. Le Prince Impérial et Ernest Lavisse, 1871-1879," *Revue des deux mondes*, Pér. VII, 50 (1930): 560-561.

¹¹ In this work the author has used the results of the balloting on the following questions:

1. March 1, 1871.	Preliminaries of peace.....	547 +	107 -
2. June 8, 1871.	Abrogation of laws of exile.....	472 +	97 -
3. Aug. 30, 1871.	Constituent powers of Assembly.....	434 +	225 -
4. May 24, 1873.	Overthrow of Thiers.....	360 +	344 -
5. June 24, 1873.	No civil funerals.....	413 +	251 -
6. Nov. 19, 1873.	Demand for a plebiscite.....	88 +	492 -
7. Jan. 30, 1875.	No Wallon amendment.....	352 +	353 -
8. Feb. 25, 1875.	No support to constitution.....	254 +	425 -
9. July 23, 1875.	No dissolution of Assembly.....	400 +	84 -

The political opinions of the deputies were determined in the following manner (X stands for abstentions):

Vote	1	2	3	4	5	6	7	8	9
Bonapartists.....	+	+	+	+	+	+	+	+	+
Legitimists.....	+	+	+	+	+	-	+	+	+
Orléanists.....	+	+	+	+	+	-	+	-	+
Center deputies.....	+	+	+	+	+	-	-	-	+
Conservative Republicans....	+	+	+	-	-	-	-	-	X
Republicans.....	-	-	-	-	-	-	-	-	X
Radical Republicans.....	-	-	-	-	-	-	-	-	-

¹² Seven hundred and sixty-eight deputies were elected to the National Assembly, but after the ratification of the preliminary peace the deputies of Alsace and Lorraine resigned, leaving only 736 deputies. On June 1, 1871, Belfort was given one representative. On account of multiple elections and recent deaths only about 680 deputies met in Bordeaux on February 12, 1871. The division into parties, mentioned above, is not based on the political opinions of the deputies elected in July, 1871, to fill the existing vacancies, but on those of the representatives elected in February.

uties, the Bonapartists 30, and the Republicans only 200,¹³ are too favorable to the conservatives, even when possible changes of opinion are taken into consideration.

The political opinions of the country are still more difficult to ascertain than those of the deputies. No electoral statistics exist for this election. The student has to rely for his information on the reports published in the *Journal officiel* at the time of the verification of the elections. Very often, however, this source does not furnish the number of eligible or actual voters or even the number of votes obtained by each candidate. When the latter are given the result is frequently unreliable, since it does not include the votes of the army. Therefore the votes of the representatives in the National Assembly remain the only index.

In order to determine how far these deputies truly represented the political tendency of their districts various methods may be employed. The one used by most authors consists in judging the real political orientation of the country by means of the by-elections between 1871 and 1875. Since on most of these occasions Republican candidates were elected, the National Assembly with its Monarchist majority is usually regarded as misrepresenting the real orientation of the nation.¹⁴ However, the divisions among the Royalists and the abstentions of many conservative voters furnish an explanation for these Republican majorities which, as A. Lajusan has shown,¹⁵ were only temporary and disappeared in such a crucial election as the one of 1877.

Another method of determining the political opinions of France in 1871 might be based on the results of the elections in 1876 and 1877. It is true that such a method would be unfair to the Royalists who, during the intervening five to six years, had made the restoration of a monarchy in France impossible by their internal divisions and therefore stood discredited in the public eye. Moreover, the elections of 1876 and 1877, unlike those of 1871, were based on the *scrutin d'arrondissement* and not on the *scrutin de liste*, with the result that Monarchists as well as Republicans failed to present

¹³ Seignobos, Ch., *Le Déclin de l'Empire et l'établissement de la Troisième République* (Paris, 1921), p. 284; Hanotaux, *op. cit.*, p. 38.

¹⁴ Seignobos, *op. cit.*, p. 284; Zévaès, *op. cit.*, p. 100; D. Halévy, *La Fin des notables* (Paris, 1930), pp. 42-43.

¹⁵ Lajusan, A., "Les Origines de la Troisième République. Quelques éclaircissements, 1871-1876," *Revue d'histoire moderne*, 5 (1930): 419-428.

candidates in many of the smaller districts where the fight seemed hopeless, and thus lowered their total vote for the department. Nevertheless, the elections of the late 'seventies furnish the only existing index, though a very imperfect one, to the political orientation of France after the overthrow of the Empire.

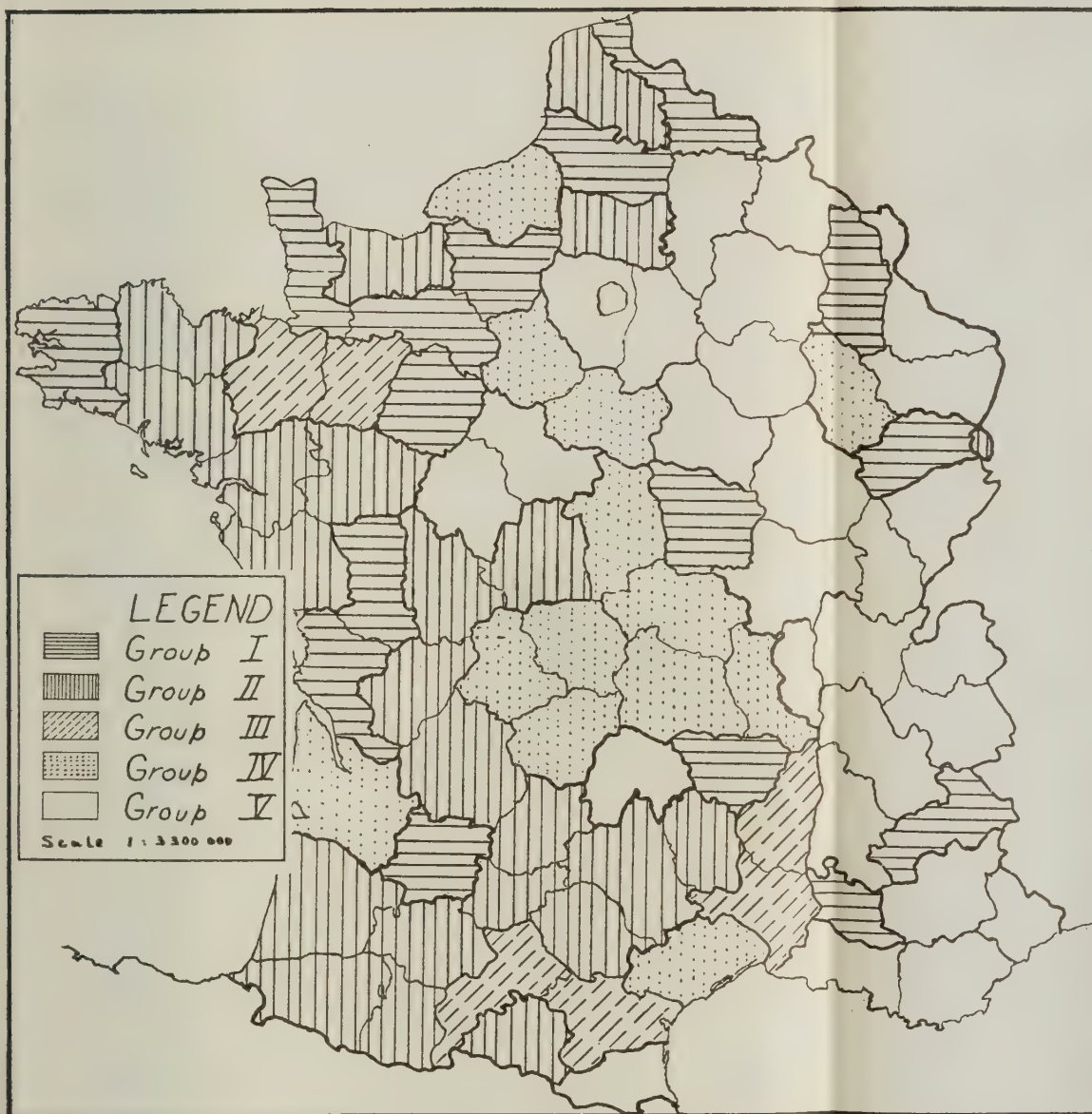
The results of the elections of 1876 and 1877, as compared with those of the 1871 election, indicate a division of the departments of France into five groups. One group could be composed of those departments which in 1876, as well as in 1877, showed a Monarchist majority. It seems fair to assume that these districts were deeply devoted to the Royalist cause in 1871, for in 1875 the conservative groups, greatly discouraged, put forth little effort to win the individual contests. A second class of departments might be created from those which in 1876 or 1877, but not at both times, showed a Monarchist majority. Though the effort of the Duc de Broglie to stem the Republican tide partially vitiated the election of 1877, these departments might well have possessed a Monarchist majority in 1871 in consideration of the Royalist *débauche* in the following years. A third division might be made of those districts in which a change of two per cent of the voters from the Republican to the Monarchist side would have given the latter a majority. Such departments belong in the doubtful class, and an equal division of the deputies between the two opposing factions seems indicated. The fourth and fifth groups would include those departments which had a vast Republican majority in 1876 as well as in 1877. Such

ELECTORAL RESULTS IN 1871

Group	Results in 1871			Corrected results		Number of departments
	Mon.	Center	Rep.	Mon.	Rep.	
1	143	4	32	179	...	24 *
2	95	3	45	143	...	16
3	39	..	13	26	26	6
4	76	2	31	...	109	13
5	36	4	214	...	254	30 †
Total	389	13	336	348	389	

* Includes the Territory of Belfort.

† Includes twenty-eight French departments, Algeria, and six colonies counted as a unit.



MAP 46. French Electoral Results in 1871, 1876, and 1877

- Group I. Monarchist majority in 1871, 1876, and 1877
- Group II. Monarchist majority in 1876 or 1877, but not in both
- Group III. Small Republican majority in 1876 and 1877
- Group IV. Republican majority in 1876 and 1877, but not in 1871
- Group V. Republican majority in 1871, 1876, and 1877

departments may be counted in the Republican column without hesitation. In only thirteen of these forty-three departments was a Monarchist majority, instead of a Republican one, elected in 1871. These districts might be separated into the fourth group to show in what regions of the country the Republicans were underrepresented in 1871. (See Map 46.)

A division of France into the five groups mentioned above gives the results shown in the table on page 482.

From this analysis it appears that the country was probably not overwhelmingly Republican in 1871, but rather equally divided between the opposing parties. In fact, if the six doubtful departments in group three were to be counted entirely in the Monarchist column, the Royalists would have a majority of eleven, and the results would be practically identical with the outcome of the 1871 elections. Consequently, in consideration of the elections of 1876 and 1877, the much-talked about misrepresentation of the French nation in the National Assembly from 1871 to 1875 seems rather doubtful.

LIDDELL'S LAWS OF ENGLISH RHYTHM

AMOS R. MORRIS

WHEN Coleridge, in 1816, published *Cristabel*, with a note on his metrical technique, he founded a school of prosody as distinctly opposed to the classical traditions as the romantic poetry was itself a movement away from those traditions. What was new, however, was not verse practice but verse theory. Poets had been writing for more than four hundred years in virtual conformity to the rules of stress as Coleridge later formulated them. The intervening hundred and twenty years have seen little refinement of his crudely conceived prosody, and teachers of English poetry go on still in rather scandalous ignorance of the fine shades of tone that make the beauties of the English phrase, whether in verse or prose. Professor Mark Liddell is in our generation, perhaps, the leading champion of the Coleridge school of stress scansion. It is now possible, for the first time, to make an objective test of his *Laws of English Rhythm*. I present here only a partial checking of those laws as he published them in 1914.¹

His fundamental idea is that, because English is a stress language, the gradation of stress is the dominant factor in determining the nature of the rhythm in the English sentence or verse. Naturally enough, he finds the conventional marking of two degrees of stress (or time) utterly inadequate. "To attempt to note," he says, "all the subtle variations of an English verse by the combinations of the makron and the breve is like attempting to note a singing scale by two letters." Instead of two degrees, he proposes a six-step scale. Upon the basis of these six degrees of stress he formulates a whole series of laws, eighty-six in all, to which he finds that words conform in the various phrasings of English speech. To make the notation more graphic I have been accustomed to supplement his symbols by the use of a six-space staff. This staff must not be confused with the musical staff, where high and low are pitch; high

¹ Liddell, Mark H., *The Laws of English Rhythm* (Lafayette, Indiana, 1914).

and low are here degrees of stress or, more exactly described, of heard loudness.

f			tolls	knell		day
e	cur-				part-	
d		few				
c						
b				of	ing	
a	The		the			

There are, it seems to me, three important questions of fact to consider in an examination of Professor Liddell's position. There is the first question of how accurate is his notation of the relative stress. There is a second question of the relation of stress to the other four component physical factors, pitch, time, tempo, and tone color, in establishing a sense of rhythm. These are primarily questions of physical fact, though they involve inevitably the psychological question of perception under all these varying conditions. Then there is a third question of "art," in the higher sense, the relation of normal word stress to sense stress. Speaking to this last point, he says: "When sense-stress of a word is raised above its normal level we call the effect Emphasis. Emphasis does not often occur in English verse. . . . Sense-stress on a polysyllabic word is given to its separate syllables in proportion to their word-stress." That is treating a most important and difficult question of literary art much too cavalierly. Perhaps no question of phrasing involves finer shades of artistry than do these turns of idiom and phrasal intonation by which normal word stress is modified by sense stress. Instead of being a thing to pass jauntily with a wave of the hand, it is the main question, to the solution of which all others are directed. It is chiefly an answer to this third question that we seek when we investigate the simpler and more fundamental matters of weight of stress and interplay of rhythm-fixing tonal factors. But the answer to this must wait upon the answer to the other two.

The question of interplay of the five physical factors is an interesting one that can be only touched upon here. It must, however, be kept constantly in mind that the subjective judgment of stress, or accent as the term is commonly used, is inevitably confused in considerable measure by the presence of all the other four, each com-

peting for attention at every moment and each in a different degree in every phrase. When we have more data by which to evaluate each of these five factors we shall have to redefine what we now call accent or word stress in more exact terms of definite units of value, describing the relative stress of a word or a syllable in terms of its five component and concurrent elements. We now have the technique for doing that, and the solution of this interesting problem waits only upon the leisure of discriminating students of literary art, or perhaps the discovery of such students.

That leaves for attention at the moment the simplest of the three questions: How accurate is the subjective judgment of word stress and sense stress, guided by Liddell's six degrees? and the corollary of that: How valid are his eighty-six laws of English rhythm? To even this simple question and its corollary I can offer only a partial answer.

The measure of stress or, more exactly, of perceived loudness, is rated in decibels as recorded by the phonometer or electrical ear. This instrument is to sound what the photoelectric cell is to light; it is built to approximate closely the response of the ear to a complex tone within the frequency and energy range significant for speech. The decibel may be defined conveniently as the minimal perceptible difference in loudness between two tones, checked in this case against a pure tone of one thousand cycles.² Our galvanometer was designed and built to register zero at fifty decibels, and we place the microphone at such distance from the speaker or the phonograph as to keep the maximum response at about ninety decibels. Our measurements, then, are electrical recordings of a range of forty units of perceptible loudness as against six subjective judgments by the Liddell scale and two by the conventional dictionary markings.

The text materials used here are four short verse selections, a total of fifty syllables, electrically recorded by four readers, two faculty men and two undergraduates. After recording the reading, each one, quite independent of it, scanned the verses by the Liddell scale. Stated in tabulated form the four readings and subjective scansions are shown in the table on page 488, in which the decibel reading is translated into the letter-equivalent.

² Fletcher, Harvey, and Munson, W. A., *Journal of Acoustical Society of America*, 5 (1933): 82.

	Reader M			Reader H			Reader W			Reader Wl			Liddell
	Sc.*	Read	Tr.†	Sc.	Read	Tr.	Sc.	Read	Tr.	Sc.	Read	Tr.	Sc.
Al-	e	88	f	d	67	c	d	71	d	d	88	f	E
most	c	77	e	e	61	b	c	63	b	c	74	d	d
up-	b	55	a	a	56	a	b	55	a	b	56	a	a
on	d	82	e	a	65	c	d	68	c	c	81	e	C
the	a	62	b	b	56	a	b	57	b	b	60	b	a
west-	d	75	d	e	68	c	d	65	c	d	73	d	E
ern	b	56	a	b	60	b	d	58	b	c	60	b	a
wave	f	76	d	c	62	b	c	68	c	b	71	d	F
Rest-	e	65	c	d	68	c	c	67	c	d	71	d	E
ed	b	52	a	b	61	b	b	55	a	b	50	a	a
the	b	54	a	b	56	a	a	60	b	a	59	b	a
broad	e	85	f	d	61	b	d	71	d	d	89	f	F
bright	f	78	e	e	65	c	d	71	d	c	80	e	e
sun	e	66	c	c	63	b	c	67	c	a	78	e	F
A	a	52	a	a	62	b	b	64	c	a	51	a	a
book	c	80	e	d	55	a	f	65	c	e	75	d	E
of	b	52	a	b	60	b	b	65	c	c	58	b	a
vers-	e	76	d	e	73	d	e	71	d	d	75	d	F
es	b	55	a	a	58	b	c	55	a	c	54	a	a
un-	d	71	d	b	73	d	d	66	c	c	70	c	C
der-	b	55	a	b	52	a	d	56	a	b	62	b	a
neath	e	62	b	c	75	d	e	56	a	d	75	d	D
the	a	55	a	a	57	b	b	60	b	b	55	a	a
bough	f	79	e	b	67	c	e	69	c	d	88	f	F
In	c	62	b	b	55	a	c	56	a	a	57	b	C
the	a	55	a	b	50	a	a	55	a	b	51	a	a
spring	e	67	c	d	68	c	e	60	b	d	87	f	F
a	a	54	a	b	52	a	a	57	b	a	50	a	a
young	d	71	d	e	70	c	e	62	b	d	73	d	F
man's	e	63	b	c	70	c	e	58	b	c	70	c	e
fan-	f	68	c	d	65	c	f	62	b	c	80	e	F
cy	b	55	a	b	60	b	d	55	a	b	62	b	b
light-	e	80	e	e	62	b	e	69	c	d	76	d	E
ly	b	55	a	b	55	a	c	55	a	c	60	b	b
turns	f	72	d	d	61	b	d	60	b	b	72	d	F
to	c	53	a	b	55	a	b	53	a	a	55	a	b
thoughts	f	80	e	d	57	a	e	71	d	c	83	e	E
of	c	55	a	c	55	a	b	61	b	b	55	a	a
love	f	77	e	f	62	b	d	70	c	a	82	e	F
I	d	81	e	b	67	c	c	75	d	d	85	f	d
was	e	56	a	c	61	b	b	68	c	b	55	a	c
ev-	e	71	d	e	77	e	f	72	d	d	81	e	F
er	c	65	c	c	68	c	d	75	d	c	77	f	a
a	a	50	a	d	50	a	a	50	a	b	50	a	a
fight-	e	80	e	f	66	c	e	70	c	d	83	b	F
er	c	52	a	c	66	c	c	55	a	c	52	a	a
so	c	68	c	d	52	a	d	71	d	a	60	b	e
one	e	75	d	e	60	b	f	73	d	d	82	e	F
fight	f	68	c	f	58	b	e	74	d	d	84	f	e
more	e	60	b	g	66	c	d	68	c	c	73	d	F

* Scanned.

† Translated:

In these four readings and four scansions, a total of four hundred placings of syllabic stress, we have virtual agreement except in two places, both coming at the end of lines and both involving the same type of complex tone quality. In the phrase, "the broad bright sun," Liddell's "laws" and his own scansion indicate that the metrical pattern is retained as regular iambic, *aFeF*. All four readers give the four words as a phrasal unit of rising and falling cadence, both in their subjective judgments in scanning and in their recorded readings. In the Browning phrase, "so one fight more," Liddell again scans it as regular iambic, *eFeF*, whereas three of my readers scan it as a circumflex of rising rhythm in the first foot and falling in the second. The fourth reader (H) scans it as a regular rising rhythm, but as a unit of two feet on one continuous rise, *dEfG*. It will be noted that he here goes beyond the scale, adding a seventh step; this was probably because he perceived the stress of "fight" to be the same as that of "fighter" and perceived "more" as necessarily one degree louder. The three readers who scan the two feet as a rising-falling circumflex read it that way. The fourth subject's reading is about midway between his own scansion and Liddell's, but not quite conforming to either. His reading for the four words is 52, 60, 58, 66; his scansion translated into decibels would be about 52, 56, 60, 66; Liddell's on the same scale would be about 52, 60, 52, 60.

In this connection we should note the operation of the Weber-Fechner law in both the perception of metrical pattern and the interpretation of these data on the decibel scale. Weber's law, *the minimal difference perceptible is a constant factor of the stimulus initially active*, has been found to hold definitely within the limits of speech we are here concerned with. Since our phonometer is built to give a logarithmic response, the rhythmic effect of a succession of monosyllables at 62, 64 d.b. will be the same as a succession at 64, 66 d.b. Furthermore, a foot of 52, 60 and one of 54, 80 will both give what the ear accepts as a satisfactory succession of feet in regular rising rhythm. This is a matter of primary importance to every teacher who has occasion to mention metrical pattern in the classroom. I (M) scanned the line from Coleridge as it is written on the staff on page 490; I actually read it in this experiment as the check marks on the staff indicate; the two are in agreement metrically and both are in agreement, according to the Weber-Fechner law, with Liddell's scansion, indicated on the staff by plus signs.

f	✓						+ wave
e	+ Ab-	✓		✓		+	
d		+		on		✓ west-	✓
c		most		+			
b			up-		✓		✓ ern
a			+ ✓	+ the		+	

It will be seen here that I scanned it with the second syllable three degrees lower than the first, but read it only one degree lower; in the next foot I scanned the second syllable three degrees higher than the first, but read it five higher; yet both agree with Liddell's scansion and all make the first foot a trochee and the second an iambus; that is the important thing for the rough-and-ready purposes of classroom teaching.

Not enough data are here given to warrant a final conclusion upon even this simplest of the three questions asked. But if these findings are borne out by further determinations, the general conclusion may be drawn that the Liddell scale of six degrees of stress is a sufficiently reliable method of verse notation for classroom purposes. Where my readers fail to conform either to the conventional metrical pattern or to their own subjective judgments of the pattern, two major problems are obviously involved. Both instances occur at the end of the line, where the cadence of line unit may very well dominate and cancel out the stress factor upon which the pattern of the foot chiefly depends. In both instances, too, the last three syllables are heavily stressed, making the last foot approximately a spondee.

Upon the basis of this evidence one would not venture far in judging the validity of Liddell's eighty-six laws or his pronouncement with reference to sense stress. But it is obvious at a casual glance that in the body of material here presented his "laws" become simply fantastic. In the total of two hundred syllables involved, the stress given conforms to his laws in fifty-six instances. That, however, is not quite the proper application of his laws; in a polysyllable the laws apply only to the accented syllable. Upon that basis of the word stress there are here one hundred and sixty word placements in which the reading conforms to the laws in thirty-eight instances. Without going into intricate statistics it is rather clear that his laws are not valid at all for the readings considered.

It should be noted especially that what we have been considering

is the relatively crude material of verse. The art of verse is, of course, a primitive and crude art as compared to that of prose. A proper test of the validity of his laws should be made in the finer and subtler material of prose. When that is done we shall probably find that Liddell's elaborate array of eighty-six laws is just one more warning against the dangers of pseudo-science and the evolving of elaborate theories out of thin air in the absence of demonstrable facts.

UNIVERSITY OF MICHIGAN

PARADISE REGAINED

WARNER G. RICE

PARADISE REGAINED is generally read, and criticized, in the light of *Paradise Lost*, to which it is supposed to be a pendant.¹ To be sure, there have been objections to this view.² And indeed no very great emphasis should be placed upon Thomas Ellwood's account of how he asked the poet, "What hast thou to say of Paradise Found?" and of how Milton subsequently showed him his shorter epic with the remark, "This is owing to you, for you put it into my head by the question which you put to me at Chalfont. . . ." But the evidence of the invocation seems convincing:

I who e're while the happy Garden sung,
By one mans disobedience lost, now sing
Recover'd Paradise to all mankind,

and the two poems obviously deal with some of the same themes — temptation, for example, the conflict of truth with falseness, the attempt of Satan to pervert the good.

Many of those who are willing enough to agree that the later poem is a kind of sequel to the earlier one urge, however, that like most sequels it shows a decline of its author's powers. The style is criticized as being too bare in some places, in others overornate; it is asserted that there is too little action; that the long arguments are tiresome; that the character of Satan is faded; that Jesus is unsatisfactory; and that the whole conception is weak since, "given Christ's nature, the temptations are not tempting."³

¹ All the important books which deal with Milton and his poetry include some discussion of *Paradise Regained*; the titles of the principal essays devoted to it are listed by David H. Stevens, *Reference Guide to Milton* (University of Chicago Press, Chicago, 1930), Nos. 1123-29.

² See, for example, E. M. W. Tillyard's chapter, "*Paradise Regained: Its Relation to Paradise Lost*," in his *Milton* (New York, 1930), pp. 297-301.

³ This phrase of William Vaughn Moody's in his Introduction to *Paradise Regained* (Student's Cambridge Edition of *The Complete Poetical Works of John Milton*, p. 250) has been frequently repeated by other critics, and in general Moody's unfavorable judgments upon the poem have found a wide acceptance.

It will be impossible, within the limits of a short paper, to consider all the points at issue; but at the outset, to clear our vision, we may well bear in mind that we are likely to be prejudiced in approaching the subject of *Paradise Regained* as we are not prejudiced when we approach that of *Paradise Lost*. For the story of the Fall of Man, with the eating of the apple and the rest, belongs to Christian mythology, so that we are not disturbed when Milton manipulates these materials freely and with originality in order to make them yield a new meaning. The case is different when we have to do with Jesus. Here we find ourselves in the realm of Christian truth and of Christian doctrine, not of mythology; we approach the Savior with reverence, and, regarding him as very god, instinctively resist any unfamiliar interpretation of his actions. Perhaps our difficulties arise partly from the fact that we have been more deeply impressed by the mysteries which theologians insist upon than by the simple story narrated in the Gospels.⁴ At all events, we are somewhat repelled and puzzled by the unorthodox manner in which Milton handles his theme.

Remembering the first books of *Paradise Lost*, we are surprised to meet a Satan who is vastly different, certainly, from the indomitable commander of the rebellious legions who were cast out from Heaven. Yet this Satan is logically developed from that great Adversary. For the poet, as he himself declares in the invocation to the Ninth Book of the earlier poem, has gradually worked away from the established conventions of the epic style,

Not sedulous by Nature to indite
Warrs, hitherto the onely Argument
Heroic deem'd, chief maistrie to dissect
With long and tedious havoc fabl'd Knights
In Battels feign'd; the better fortitude
Of Patience and Heroic Martyrdom
Unsung,

and has focused his subject by the presentation of an intense inner conflict, with Satan participating as the wily seducer, the plausible contriver, who, having found out Adam's weakness, and Eve's, destroys them by craft, not by open assault. At the crisis there

⁴ It is salutary to turn, not only to the Scriptures, but also to such a book as T. R. Glover's *The Conflict of Religions in the Early Roman Empire* (London, 1909) to remind ourselves of what the historical Jesus of Nazareth actually said, did, and claimed for himself.

are no battles on the glittering plains of Heaven — only contests of minds and wills in the Garden. The great spiraling movements which lead up to the fourth and ninth books culminate by fixing attention on Man in Eden.

Paradise Regained, likewise, is designed to tell

of deeds
Above Heroic, though in secret done;

its conflicts are carried on within; its tensions are psychological and moral; it presents no physical encounters, but the shock of will against will. And, accordingly, the Satan of *Paradise Regained* is no more a panoplied warrior than is the Satan of the last books of *Paradise Lost*. But he is not the less formidable or impressive on this account. From the beginning he realizes, and forces upon us the realization, that he stands in extremest jeopardy, in a danger far greater than that which he proudly faced from his throne in Pandemonium at the first council.

And now too soon for us the circling hours
This dreaded time have compast, wherein we
Must bide the stroak of that long threatn'd wound,
At least if so we can, and by the head
Broken be not intended all our power
To be infring'd, our freedom and our being
In this fair Empire won of Earth and Air;
For this ill news I bring, the Womans seed
Destin'd to this, is late of woman born, (I, 57-65)

so that there is desperate need for his trial of all possible means

to subvert whom he suspected rais'd
To end his Raign on Earth so long enjoy'd. (I, 124-125)

This enterprise involves first a discovery and a testing. Jesus has become known in the world; he has been baptized:

I saw
The Prophet do him reverence, on him rising
Out of the water, Heav'n above the Clouds
Unfold her Crystal Dores, thence on his head
A perfect Dove descend, what e're it meant,
And out of Heav'n the Sov'raign voice I heard,
This is my Son belov'd, in him am pleas'd.
His Mother then is mortal, but his Sire,
He who obtains the Monarchy of Heav'n,
And what will he not do to advance his Son?
His first-begot we know, and sore have felt,

When his fierce thunder drove us to the deep;
 Who this is we must learn, for man he seems
 In all his lineaments, though in his face
 The glimpses of his Fathers glory shine. (I, 79-93)

And, accordingly, the whole action of the poem turns upon the Devil's attempt to corrupt, and at the same time to find out the real nature of, Christ.

Now much of our feeling concerning the events narrated is determined, necessarily, by our grasp of the conception which Milton presents of the character and being of the Savior of Man. Speculations concerning the Son of God are set forth at length in the fifth chapter of *De Doctrina Christiana*; but into that thicket of theology it is not necessary to penetrate now. It is enough to point out that from the first lines of *Paradise Regained* it is Jesus' manhood, Jesus' humanity, that the poet emphasizes. The Almighty, foreseeing what the Tempter will endeavor, declares,

He now shall know I can produce a man
 Of female Seed, far abler to resist
 All his sollicitations, and at length
 All his vast force, and drive him back to Hell,
 Winning by Conquest what the first man lost
 By fallacy surpriz'd.⁵ (I, 150-155)

All commentators note the Arianism here; but simply to say that Milton subscribes, or nearly subscribes, to a heresy is to confuse the issue. The point is that he is getting behind the accretions of theological speculation and dogma, and figuring forth the Christ of the New Testament, the greater Man who preached and walked with his humble disciples in Galilee, who asserted his kinship, and all men's kinship, to God, but not his Godhead; who, at last, cried out in agony on the Cross. Milton admirably imagines him as the inheritor of the Jewish tradition, a man brought up in the knowledge and love of the Law and of the Prophets — a Prophet himself, conscious of Messianic promptings. And this chosen One has at first shared the prevailing belief in the function of the Messiah

To rescue *Israel* from the *Roman* yoke,
 Then to subdue and quell o're all the earth
 Brute violence and proud Tyrannick pow'r,
 Till truth were freed, and equity restor'd. (I, 217-220)

⁵ The mention of Job in the verses preceding this passage and elsewhere, and the fact that Jesus is often in the poem brought into comparison with the Prophets, add to the reader's sense of his human quality.

If he has come at last to another view of his mission, finding it

more humane, more heavenly first
By winning words to conquer willing hearts,
And make persuasion do the work of fear,

it is not, Milton makes plain, without being fired by thoughts of domination and glory. In him there has been an impulse toward self-assertion. Jesus' notable victory, then, has first of all been won over a tendency to go boldly against the mighty in the world, to trust in his "calling." He has schooled himself to humility, to a reliance upon Divine Providence and its guidance:

And now by some strong motion I am led
Into this wilderness, to what intent
I learn not yet, perhaps I need not know;
For what concerns my knowledge God reveals. (I, 290-293)

Upon this pivot everything really turns. Satan, shrewdly guessing that if Jesus is to be attacked successfully on any side, it must be through an appeal to human impulses not less strong in him than in Adam, seeks first to entrap Christ by appearing in the guise of a hermit to suggest that he transform stones into bread.

But if thou be the Son of God, Command
That out of these hard stones be made thee bread;
So shalt thou save thy self and us relieve
With Food, whereof we wretched seldom taste. (I, 342-345)

The request is devilishly designed. It is casual, as though the matter were no great one, and it is abrupt; it seems charitable; it glances at the Savior's human need, for he really is hungry; but it involves great things. If Jesus undertakes to perform the miracle, he will at once have arrogated to himself extraordinary power; he will also have tacitly called in question Heaven's intentions toward himself — in both particulars satisfying his tempter. But Jesus is not to be surprised into doubt:

Think'st thou such force in Bread? is it not written
(For I discern thee other than thou seem'st)
Man lives not by Bread only, but each Word
Proceeding from the mouth of God; who fed
Our Fathers here with Manna; in the Mount
Moses was forty days, nor eat nor drank,
And forty days *Elijah* without food
Wandred this barren waste, the same I now:
Why dost thou then suggest to me distrust,
Knowing who I am, as I know who thou art? (I, 347-356)

Thus unmasked and rebuffed, Satan is still persistent. He at once returns to the assault. His long speeches, beginning with

'Tis true, I am that Spirit unfortunate . . . ,

are not designed merely for self-revelation, nor are they intended chiefly to arouse Jesus' sympathies. Their real aim, half apparent throughout, emerges clearly at the end:

Thy Father, who is holy, wise and pure,
Suffers the Hypocrite or Atheous Priest
To tread his Sacred Courts, and minister
About his Altar, handling holy things,
Praying or vowing, and vouchsaf'd his voice
To *Balaam* Reprobate, a Prophet yet
Inspir'd; disdain not such access to me. (I, 486-492)

And once more Jesus answers with perfect humility,

Thy coming hither, though I know thy scope,
I bid not or forbid; do as thou find'st
Permission from above; thou canst not more. (I, 494-496)

The pattern thus established is worked out fully in the later books of the poem. The Messiah, still hungering, wondering what his long fast portends, but still trusting in God, dreams

as appetite is wont to dream,
Of meats and drinks, Natures refreshment sweet; (II, 264-265)

and waking, is again approached by the Tempter, who reminds him that

Others of some note
As story tells, have trod this Wilderness;
The Fugitive Bond-woman with her Son
Out cast *Nebaioth*, yet found he relief
By a providing Angel; all the race
Of *Israel* here had famish'd, had not God
Rain'd from Heaven Manna, and that Prophet bold
Native of *Thebez* wandering here was fed
Twice by a voice inviting him to eat.
Of thee these forty days none hath regard,
Forty and more deserted here indeed. (II, 306-316)

It is proper enough to see in this invitation, as many critics have done, an appeal to Jesus' sense of brilliance and luxury, as well as to his strong desire for food; and Lamb was partly right in regarding his refusal as a triumph of temperance. But there is more here — a modesty and a reverent caution which will not admit the assumption implied in Satan's flattering questions,

What doubts the Son of God to sit and eat? . . .
What doubt'st thou Son of God? sit down and eat.

The indirectness of Christ's answers must not be taken, then, as indicating a wish to torment and exasperate Satan, though his words certainly have this effect: the point is that under the circumstances assertion would be unfitting; irony must suffice:

Said'st thou not that to all things I had right?
And who withholds my pow'r that right to use?
Shall I receive by gift what of my own,
When and where likes me best, I can command?
I can at will, doubt not, assoon as thou,
Command a Table in this Wilderness,
And call swift flights of Angels ministrant
Array'd in Glory on my cup to attend:
Why shouldst thou then obtrude this diligence . . .? (II, 379-387)

Still the Adversary continues — offers riches, fame, and finally glory, reminding the Son that glory is not disdained by the Father himself. It is a subtle shift, and the more dramatic because Satan, not the least of the angels, has fallen into irretrievable ruin precisely because he could not resist his desire to rival the Almighty in glory.⁶ But Jesus is steadfast, not to be betrayed, though he is greatly moved as he "fervently" replies to Satan's insistence upon God's delight in glory,

And reason; since his word all things produc'd,
Though chiefly not for glory as prime end,
But to shew forth his goodness, and impart
His good communicable to every soul
Freely; of whom what could he less expect,
Then glory and benediction, that is thanks . . .?
But why should man seek glory? who of his own
Hath nothing, and to whom nothing belongs
But condemnation, ignominy, and shame? . . .
Yet, sacrilegious, to himself would take
That which to God alone of right belongs. (III, 122-141)

⁶ Charles Williams, in his stimulating essay on Milton in *The English Poetic Mind* (Oxford, 1932), pp. 122-123, puts the point well:

"Omnipotence is engaged upon something to which Satan is with his whole nature antagonistic. Reason bids him submit — God and Raphael both point this out: even after his fall from Heaven he considers the possibility. To do that, however, would be precisely to lose *himself*; he would be something other than he is. He must act from what he is, and he expresses this in a minor contradiction. When he is addressing his followers he points out that none of them will envy him his throne; no one will want 'the greatest share of endless pain.' Reasonable enough, true enough; only it is precisely this which he himself must

Though it is grandly elaborated, the promise of a kingdom seems something of an anticlimax after this. But we must not forget the power of the Messianic dream, of which the poet seeks to remind us by the opening passage in Book II, or of Jesus' youthful acceptance of the idea of conquest and domination over the princes of the earth. His lengthy replies to Satan are, then, more than displays of rhetoric; and they show more than the power of reason to discover falseness. They are outpourings of thoughts long revolved and treasured up, Christ's assurances to himself that his rejection of violent measures and his decision to "make perswasion do the work of fear" are just. In a sense they serve the purpose of soliloquies. And again the conclusion is that God's will must be done. Not even to rescue the Chosen People can Jesus be tempted to think of accepting the proffered aid:

no, let them serve
 Thir enemies, who serve Idols with God.
 Yet he at length, time to himself best known,
 Remembring *Abraham* by some wond'rous call
 May bring them back repentant and sincere,
 And at their passing cleave the *Assyrian* flood,
 While to their native land with joy they hast,
 As the Red Sea and *Jordan* once he cleft,
 When to the promis'd land thir Fathers pass'd;
 To his due time and providence I leave them.⁷ (III, 431-440)

The prospect of the glories of Greece, reserved until the end, closes up this series of trials, and it is the greatest of them all. That Milton should review the intellectual achievements of the mighty ancients only to reject them has seemed shocking to many; the violence of his renunciation has been thought to declare the strength of the claim of those secular studies which so long delighted and supported him. But it is equally proper to apply this interpretation to the protagonist of Milton's poem, to Jesus. It is accordant with the character here given him that the powerful appeal of human wisdom, of human philosophy, should call out a determined denial:

demand. 'Better to reign in Hell than serve in Heaven.' This contradiction is not deliberate deceit; it is the irrational strength of his nature. . . . Milton stresses the moral choice in the contradiction, the choice which so many men have made, the preference for the existence of their own will as the final and absolute thing as against the knowledge (whatever that may be) of some 'great commanded Good.'

Williams' excellent comments on *Paradise Regained* appear on pages 135-143 of his book.

⁷ Cf. III, 182-197.

Alas what can they teach, and not mislead;
Ignorant of themselves, of God much more,
And how the world began, and how man fell
Degraded by himself, on grace depending?
Much of the Soul they talk, but all awrie,
And in themselves seek vertue, and to themselves
All glory arrogate, to God give none.⁸ (IV, 309–315)

So we are brought to the final climax. Satan has gained no satisfaction, has won no victory, has found no answer to his question. Frustrated, “swoln with rage,” he cries out that he has discovered in Jesus no more than human constancy,

And opportunity I here have had
To try thee, sift thee, and confess have found thee
Proof against all temptation as a rock
Of Adamant, and as a Center, firm
To the utmost of meer man both wise and good,
Not more; for Honours, Riches, Kingdoms, Glory
Have been before contemn’d, and may agen:
Therefore to know what more thou art then man,
Worth naming Son of God by voice from Heav’n,
Another method I must now begin. (IV, 530–540)

And this “method,” indeed, seems certain to yield decisive results. He sets Christ upon the pinnacle of the Temple, challenging in scorn:

There stand, if thou wilt stand; to stand upright
Will ask thee skill; I to thy Fathers house
Have brought thee, and highest plac’t, highest is best,
Now shew thy Progeny; if not to stand,
Cast thy self down; safely if Son of God:
For it is written, He will give command
Concerning thee to his Angels, in their hands
They shall up lift thee, lest at any time
Thou chance to dash thy foot against a stone. (IV, 551–559)

Jesus’ dilemma seems now desperate indeed; but once more the answer comes, confident, calm, crushing in its reproof. It is the answer of Samson: “All the contest is now ’twixt God and *Dagon*.” In his moment of apparent peril he does not yield one whit. His trust is in the Almighty, in the Divine Providence which may dispose of him as it will for the accomplishment of its hidden purposes. He replies,

⁸ Milton would have man’s reason guide him in accordance with God’s law in obedience. Metaphysical speculation, the pride of the mind, he distrusts. The fallen angels “found no end, in wandring mazes lost” (*P. L.*, II, 557–569), and the Angel warns Adam to be “lowlie wise.”

Also it is written,
Tempt not the Lord thy God, he said and stood.
But Satan smitten with amazement fell. (IV, 560-562)

Thus by humility, by constant faith, the contest is decided.⁹
Now can Christ be borne to Heaven, now declared "True Image
of the Father," and assured that

A fairer Paradise is founded now
For *Adam* and his chosen Sons, whom thou
A Saviour art come down to re-install. (IV, 613-615)

And thus is sung

Recover'd Paradise to all mankind,
By one mans firm obedience fully tri'd. . . .

When we reflect upon it, we can scarcely think it surprising that
the "second Adam" should thus illustrate the lesson which the first
Adam learned as a result of the fall, namely,

that to obey is best,
And love with feare the onely God, to walk
As in his presence, ever to observe
His providence, and on him sole depend. (*P. L.*, XII, 561-564)

And it is surely fitting that a Christian poem should stress this
idea; for man, after his ruin, can no longer trust to unobscured
reason, but must depend upon God's grace to set him on even ground
against his mortal foe, and so is bound to acknowledge a double
debt. Milton learned to subdue his own assertiveness; its power
in his nature marks the extent of his victory. His pride at last
comes to be the pride of God's servant, the pride of one who, recog-
nizing his true place, can say

They also serve who only stand and waite.

It is this aspect of the poet's achievement which Landon has
expressed in his fine lines on "Shakespeare and Milton":

The tongue of England, that which myriads
Have spoken and will speak, were paralyzed
Hereafter, but two mighty men stand forth

⁹ This interpretation of the significance of Christ's answer does not agree with the usual view; see Dowden's essay on *Paradise Regained*, in *Milton Memorial Lectures, 1908* (London, 1909), pp. 209-210. Yet this interpretation seems to me to be fully in accord with the central meaning of the poem.

Above the flight of ages, two alone;
One crying out,

All nations spoke thro' me.

The other:

True; and thro' this trumpet burst
God's word; the fall of Angels, and the doom
First of immortal, then of mortal, Man.
Glory! be glory! not to me, to God.

THE NATURE OF THE QUESTION, "ARE THERE THREE CONSECUTIVE 7'S IN THE EXPANSION OF π ?"

ALICE L. AMBROSE

I WISH to consider certain expressions of a mathematical kind, with a view to analyzing these and the mathematical questions they seem to answer. Though I shall discuss only a few specific assertions about the decimal expansion of π , comments on the questions they would, upon proof, be answers to, hold good for other mathematical questions, and will serve to make a general distinction between mathematical and empirical questions. What I shall have to say is due in large part to suggestions made in lectures on this and related topics by Dr. L. Wittgenstein (1935) at Cambridge University. But I make no attempt and no claim to expound his views.

I wish to suggest that certain expressions in mathematics having the appearance of questions are in important respects not questions at all, or at least that they are not questions in the ordinary sense. Let us consider:

(a) There are three 7's at the n th, $n + 1$ st, $n + 2$ nd places in the decimal development of π .

(b) There are three 7's at the 800th, 801st, 802nd places in the decimal development of π .

In what sense these are answers to questions will appear in the analysis of the questions they seem to answer. And at the same time, in what sense expressions for these questions do set questions will appear in the analysis of the relations of seeming answers to them. Expression (a) would seem to answer the question, "Are there three consecutive 7's in the decimal development of π ?" But unless (a) is like "There is always a prime greater than any given prime," which answers the question, "Is there a prime greater than a given prime?" and the proof of which at the same time provides the answer to "What is a prime greater than the given prime n ?" then the

expression (a), "There are three 7's in π ," seems to answer one question and to set one which it cannot answer, namely, "At *what* places are there three consecutive 7's in π ?" The latter question would be answered by some such proposition as (b), for proof of (a), that there are three 7's at the n th, $n + 1$ st, $n + 2$ nd places, obviously fails just in making the specification of n required.

Now, as is well known, neither (a) nor any proposition such as (b) is the result of any set of propositions or of calculations which could be said to prove them. This is one sense in which I mean to hold that they are not *answers* to the questions, "Are there three 7's?" and "At what places are there three 7's?" To say that they are answers because they would be termed so were they the result of proof is to state an unclarity. For we have no idea what the supposition, "were they the result of proof," is like in advance of producing the proof. Now to say that (a), "There are three 7's at the n th, $n + 1$ st, $n + 2$ nd places in π ," is in the sense given above not an answer to the question, "Are there three consecutive 7's in π ?" will involve holding that in some sense the latter expression is not a question. This sense is specified in saying that we cannot see in advance of proof either that (a) or that (a)'s formal negative answers this question; that is, to see that one or the other is an answer would be to see how it is. It is peculiar to call an expression a question if one does not know what either the negative or the affirmative answer would be like in advance of finding that answer. In contrast to the expression, "Are there three 7's in π ?" stands the genuine question, "Are there political prisoners in the Salzburg Festung?" Here, before the answer is given, one knows what either possible answer is like — one knows what one would call an answer.

Now one might say that one knows what an affirmative answer to "Are there three 7's?" would be like, since one knows exactly what the appearance of three 7's in an expansion looks like. Granting that one does not know what an answer would be like which would result from a proof not specifying the position of the three 7's, one still holds that one knows what an affirmative answer would be like in knowing what is meant by "the appearance of three 7's." But knowing what is meant by this is knowing merely what it is to write down three 7's by some calculation or other. To write down three 7's is, of course, by no means to write down the result of *the* calculation of π (say the expansion of the function $4 \left(\arctan \frac{1}{2} + \arctan \frac{1}{3} \right)$).

To write down the result of *the* calculation I take to be knowing what it is like for an affirmative answer to be given. To know what it is for three 7's to appear as the result in the course of expansion would be equivalent to knowing the answer to the question, "At *what* places are there three 7's?" And this question is constructable only after the answer is given. That is, an answer in the sense of a result of calculation, which might read, "Between *these* steps of the expansion three 7's occur," would need to be given before the question, "At what places . . .?" could be asked. For "At what places . . .?" if it is a question to which we know what an answer would be like, is of the form, "At what places between these steps of the expansion?" not "At what places between these steps or these steps or these . . . (*ad inf.*)?" And with the specification of "these steps" one has either specified or made possible the specification of the position of the three 7's. A question which cannot be asked until an answer is produced is hardly to be called a question — and obviously need not be asked after an answer is given. To put this question, "At what places . . .?" before the answer is given is to presuppose an affirmative answer without knowing what such an answer would be like. To know what an answer would be like seemingly is prerequisite if the expression is to express a question. But so soon as one knows what an answer would be like, one knows *the* answer, whereupon to put the question is pointless. This puzzling situation exists because we are unclear what it is to presuppose an affirmative answer when we have no method for deciding whether the three 7's are at certain places *and not at the rest*. In large part, we are unclear because we are at the same time asking whether there is the question, "At what places . . .?" We cannot ask the question, "At what places . . .?" so long as we are questioning whether there is an answer to the prior question, "Are there three 7's . . .?" But even though we had a proof of which "There are three 7's . . ." was the result yet which did not specify the position of the three 7's, in the peculiar sense described above, there still is no *question*, "At what places . . .?"¹

¹ It might be held that puzzles about the question, "Are there three 7's in the expansion of π ?" are gratuitously created by the use of the phrase, "the expansion of π ." The latter suggests that there is an expansion of infinite extent which is there, but which one cannot run through in order to decide the question. This is, I believe, not the case. There is always a finite number of expansions rather than *an* expansion. However, puzzles still persist, even though one re-

Let us examine further the presupposition of the question, "At what places . . .?", namely, that there are three 7's. It is a convention that "At the 800th, 801st, 802nd places there are three 7's in π " (which, "were it the result" of a calculation, would be an answer to "At what places . . .?") entails "There are three 7's in π " (which, "were it the result" of a proof, would be an answer to "Are there three 7's . . .?"). The two "questions," "Are there three 7's . . .?" and "At what places are there three 7's . . .?" obviously are not equivalent, since the one makes the presupposition that there are three 7's and the other does not. The question which "There are three 7's in π " seems to answer is like the question, "Do there exist an x , a y , and a z , and an $n > 2$ such that $x^n + y^n = z^n$?" As has been pointed out, we cannot say in advance of answering such questions what sort of answer would have to be given in order to be accepted as an answer. For we cannot picture the complex of propositions of which "There are three 7's . . ." is the result. That is, we do not know what an answer would be like. On the other hand, we do in some sense know what it would be like for some such proposition as, "At the 800th, 801st, 802nd places there are three 7's . . ." to be an answer to "Are there three 7's . . .?" We know it in the sense that "to be an answer" is to report the result of a specific calculation which we take as giving the expansion of π , say, the expansion of the function $4(\arctan \frac{1}{2} + \arctan \frac{1}{3})$. Knowing *a method*, then, for giving an affirmative answer is knowing in one sense (1) what would be accepted as an affirmative answer. On the other hand, as has already been pointed out, knowing what an affirmative answer is, in another sense (2) is knowing what *the* answer is. To know what an affirmative answer is like in the first sense is to know *a method for proving* one of a disjunction which is in fact endless, i.e. for proving either "At the 800th, 801st, 802nd places . . ." or "At the 855th, 856th, 857th places . . ." or And, in the second sense, it is to know what it is like to *prove* one of a finite disjunction *by* this method. Because it is logically impossible for an infinite disjunction to be written, knowing what an answer to "Are there three 7's . . .?" is like in the first sense means knowing a method for giving an affirmative answer, but not for giving a negative one. One might

formulates the question as: "Are there at the n th, $n + 1$ st, $n + 2$ nd expansions three 7's?"

describe the two senses in which one knows what an affirmative answer such as, "At the 800th . . . places there are three 7's," is like by saying that two different questions are answered. To know a method for giving an affirmative answer only is to know what an answer is like to the question, "Are there three 7's . . . ?" whereas to know what it is like to prove one of a finite disjunction by this method is to know what the answer is like to the question, "Are there three 7's or not?" Here I use the alternative *p* or *not-p* in any situation where the *same* test serves to give *both* affirmative and negative answers — e.g. in the situation where one asks whether there are three 7's at the 800th, 801st, 802nd places. In the situation where one asks whether there are three 7's at *some* places, were this question to be put as "*p* or *not-p*?" what the "*not-p*" would be like is utterly unknown except in the sense that the method for giving an affirmative answer to "*p* or *not-p*?" is by convention a method for proving "*not-not-p*." We have here no alternative in which we know what each possibility is like, and, granting that in one sense we know what the possibility *p* is like, we do not know in at all the same sense what the possibility *not-p* is like. Thus the sense in which "At the 800th, 801st, 802nd places there are three 7's" is an answer to "Are there three 7's?" is the sense in which we have a method allowing us to say *that* three 7's exist, but not *whether* or *not* three 7's exist. For the method is not a method for determining that they do not.

It is well known that there is no general method which serves both to prove whether there are and whether there are not three 7's in π . Nor do there exist two methods, one for proving an affirmative answer if that answer is to be given, and one for proving a negative answer if that answer is to be given. I wish to say that, as the word "question" is ordinarily used, a question about existence would seem to be, "Are there or are there not?" and an answer therefore would show *whether* there are or not. The question, "Are there three 7's . . . ?" is not the question, "Are there or are there not?" if we mean by the latter a question for which we know what both alternants would be like through knowing what answers to them would be like. The only answer for which we know at all what it is like, through knowing a method for proving one of an endless disjunction, is affirmative. As already pointed out, we do not in one sense know what a method for proving one of an endless dis-

junction is like; and the answer which is the formal negative of this and which would answer the other question of the alternative, we do not know in any sense. Thus in the sense in which we cannot ask the question "whether or not?", "Are there three 7's?" is not a question. For purposes of comparison let us consider genuine questions for which there is a method providing either a negative or an affirmative answer, and which therefore are questions "whether or not?" Let us consider "What is the area A under the curve $y = x^3$ between $x = 1$ and $x = 3$?" which is answered by integrating between the limits. This method one knows in advance will give the answer to this question and to any such question as, "Is the area A equal to 27 or not?" Similar comments may be made on the questions, "Is the product 23×26 equal to 598 or not?" "Are there three 7's at the 800th, 801st, 802nd places or not?" And empirical questions such as, "Are there prisoners in the Salzburg Festung?" are similar to these in that "There are not" can conceivably be verified by the same method as "There are."

By this, however, I do not mean to suggest that a proposition in mathematics which is shown to be an answer to a question by a general method of proof which would serve to show its formal negative to be an answer in the same sense is precisely like an empirical proposition. Nor will, therefore, a mathematical and an empirical question be alike. I wish here to discuss an important difference. In this paper I have treated "answers" to mathematical questions as results of proofs, or reports on results of calculations, as the case may be. For purposes of comparison, then, I shall look at empirical propositions in terms of a possible proof. Let us examine, first, the phrases, "proof that p is the case" and "proof whether or not p is the case." Note that to a question such as, "Does $\int_1^3 x^3 dx = 27$ or not?" the answer could not be otherwise than what the calculation shows, for one of the alternants of "whether or not" is impossible. If the answer in this case is 27, we cannot imagine what it would be like for it not to be, and if it is not 27 we cannot imagine its being this. For to do so would be to imagine a calculation specifically different from integration, by which $A = 27$ is the result. And imagining a different calculation, like imagining a poem, is equivalent to creating the calculation, and the poem; whereas imagining the proof of an empirical proposition is not equivalent to having carried it out,

The phrase "proof that p " in mathematics — at least in number theory — has no significant opposite. Proof that p could not be otherwise and be called proof. Actually, there is no *proof that p* is true in the sense of "proof that p is true and not otherwise" if the phrase, "and not otherwise," is supposed to indicate a possible alternative. For p could not be otherwise. This distinguishes the usages of the phrase "proof that" in connection with empirical propositions and propositions of number theory. With an empirical proposition such as, "There are prisoners in the Salzburg Festung," the sense in which we prove *that* it is true is very different. We have a picture of what it is to prove that prisoners are lying in the Festung in the sense of proving that this is true and not otherwise. For it could be otherwise. And the sense of "proof *whether* there are prisoners . . ." also differs from "proof *whether* there are three 7's in π " and from "proof *whether* a given geometrical theorem is true," viz., it is conceivable that the same test would in the first case give either an affirmative or a negative answer, while in the other two cases an affirmative answer would be an answer by virtue of one bit of mathematics, and a negative answer an answer by virtue of an entirely other bit. That is, each would be an answer by virtue of different types of proof.

But now I wish to say that, if the word "question" as ordinarily used in the phrase, "questions about existence," means "Are there or are there not?" and, therefore, if the answer shows *whether* there are, then even though a question in number theory asks whether there are, it is by contrast with an empirical question not a question. I have already pointed out that in a question such as, "Are there three 7's at the 800th, 801st, 802nd places or not?" one of the alternants is impossible. In consequence, just as $(p \vee \sim p) \vee (p \sim p)$, which is taken in the *Principia Mathematica* of Whitehead and Russell as a special case of $p \vee \sim p$, is in some sense not a proper *alternative*, since one of the terms is no possibility, so is it with the mathematical alternative above, where one of the alternants is no possibility. Perhaps I have succeeded in doing no more here than saying that "question" and "answer," "proof that p " and "proof whether or not p " are used in very different senses, according as mathematical propositions of the kind given above or empirical propositions are concerned. It is, in fact, to say something about what we mean by certain mathematical propositions being analytic

to point out that though an empirical proposition, say, that there are prisoners in the Festung, is proved true, it nevertheless makes sense to say it is not true, whereas with certain mathematical propositions this is not the case. What I have aimed at doing here is to show the variations in sense of phrases used about such mathematical propositions as these, which variations are consequences of "these propositions are analytic."

Before leaving this discussion of mathematical questions, I wish to note that there is a sense in which either alternant of "Does $\int_1^3 x^3 dx = 27$ or not?" may sensibly be supposed to be the case: the sense in which it is being asked whether a mistake in calculation has been made. Thus, it is meaningful to suppose $\int_1^3 x^3 dx = 27$ (which is erroneous) in contrast to supposing $\int_1^3 x^3 dx = ax^2 + 2bx + c$. Here, again, it is interesting to compare what a mistake in stating a mathematical equality and in verifying an empirical hypothesis is. A mistake made in verifying the hypothesis that there are prisoners in the Festung might consist in failing to see figures huddled in corners or in not weighing accurately other evidence. On the other hand, a mistake made in answering a mathematical question by doing a calculation for which the rules are known consists in writing down figures not in conformity with those rules (e.g. multiplication, exponentiation, integration). Since one has not set up rules for a different calculation, one is in a sense doing no calculation. For one is writing down figures according to no rule.

It is certainly true that most of the important "questions" asked in mathematics are not questions about errors in calculation, nor are they like "Are there three 7's at the 800th, 801st, 802nd places or not?" But, rather, they are such that the answer will be the result of a proof which has yet to be produced. And, in general, such a proof does not serve to give an affirmative answer in the same sense as it would give a negative answer (i.e. most questions are not to be answered by propositions the range of whose field of reference is finite). Of these we do not know in advance what we should accept as an answer, whether that answer be affirmative or negative. And in this sense they differ from what we ordinarily call questions, or, as I have put it, in this sense they are not questions. I do not wish to say that they are not in any sense questions.

They obviously are. But I do wish to hold that any expression of the form, "Can one prove p ?" which one sets oneself about a mathematical p , is not to be analyzed as a question about one's abilities to answer it. It is a question about what the postulates and the definitions imply. It does present a challenge to one's abilities because one understands the meaning of the terms in p and because one understands combinations of terms similar to p . But one has no idea what it would be to exhibit just the combination of terms p as the result of a proof, any more than one has an idea what it would be to produce the number 5 at the fifth decimal place in π if one had no method for calculating. In such a case there is no answer until what we would call an answer is produced, and no question before there is an answer.

In this paper I have tried to specify how certain mathematical questions differ from ordinary questions. I think it might be even more difficult to specify precisely the sense in which questions in mathematics *are* questions.

UNIVERSITY OF MICHIGAN

THE NEUROTIC MURDERER *

LOWELL S. SELLING

ABNORMAL psychology is interested in atypical behavior of all sorts. Of all the varieties of unusual behavior that one can enumerate, murder is possibly the most interesting and, unfortunately for science, but perhaps more fortunately for the common citizen, one of the most inaccessible for study.

There are definite limitations to study of the murderer. These are limitations of technique and of material, as well as of a social and legal nature. The courts and the prisons do not take favorably to investigations made by persons not directly connected with the problem involved; court attachés as well as prison guards are given a better opportunity to study the offenders' make-ups and to generalize about them than is the trained student of personality. Before trial only the promise of assistance by the investigator can loosen the tongue of the accused, and this no researcher can honestly promise; after trial, the offender can see no reason to tell his story to an outsider.

In the scientific obscurity which envelops the motivation and type psychology of the murderer, there is noted an even deeper shadow. Here unnamed and unanalyzed forces and conditions are interwoven to form a problem complex which needs exploration and excavation. Here is the problem of the interrelation between neurosis, psychoneurosis, and murder.

The writer is using the term "neurotic" as synonymous with "psychoneurotic" to mean "diseased with a functional mental disorder not severe enough to be a psychosis, but sufficiently grave to cause discomfort and to cause awareness of certain definite symptoms or signs."

Theoretical explanations serve to complicate the matter. Proponents of the simple escape, the Adlerian, the individual psychological, and the Freudian approaches have all presented logical

* From the *Psychopathic Clinic of the Recorder's Court*, Series P, No. 3.

interpretations of cases studied. Each theory tends to explain in part the mental mechanism involved in the act of murder, but all can be criticized for failure to adhere to the specific definition given above. With theories of the neuroses, all contribute, none satisfy.

But the problem of the neurotic murderer is a practical one and must be solved for courts and for society. It is not vast. In Detroit, where there are about sixty homicides of all sorts each year, the neurotic murderer is noted in fewer than five cases; in fact, there seem to have been whole years during the history of our clinic when the diagnosis was not made in even one case.

Because of the paucity of material, a comprehensive classification of the neurotic murderer is not possible, but the writer in making this, necessarily only a preliminary, study, has attempted to outline and illustrate the possibilities of neurotic mechanisms entering into the particular crime situation of homicide.

The first type is the basically neurotic individual who commits murder and whose crime is symptomatic of his diseased mind. He may kill to escape from some mental persecution. He may kill some person to whom he feels inferior, thus compensating. On the other hand, as the Freudian school points out, there may be an identification situation where, for example, the victim is identified with the hated father.

The second kind of neurotic murderer is the individual who is not neurotic before the immediate circumstances surrounding the crime occurred, but who, when committing it, or shortly after its commission, passes into an escape situation, losing his memory or even his mind as a whole. Perhaps exaggerated forms of this reaction are the so-called Ganser's syndrome, or under some conditions the poorly characterized mental-disease entity, the prison psychosis. I do not, of course, include here the deliberate malingerer whose symptoms are chosen deliberately and carefully, although I must admit that there is an unquestioned element of the psychoneurotic in any person who attempts to escape from trouble by the deliberate pretense of disease. This I have discussed elsewhere.¹

To illustrate the classification given above I have selected a few cases, more or less at random, intended to show the problem as it presents itself to the criminological psychologist.

Case No. 1 is that of a man who was referred to the Recorder's

¹ Selling, L. S., *Diagnostic Criminology*, p. 139.

Court Psychopathic Clinic in its early days (before the writer was connected with it), having been found guilty of murder in the second degree. He had killed his second wife. His past history indicated that he was never entirely satisfactorily adjusted. His father drank heavily and whipped him frequently. Our patient admitted that he had always lived with his mother, and when she was dying of cancer, he married a girl, his first wife, with whom he had been going for some time, in order to have a home in the event of his mother's death. He later was divorced. At the time of his examination he had no idea where his daughter by this marriage was. His mother died shortly after his marriage and the patient stated that he was affected so greatly by his mother's death that he could not attend the funeral. This is a very significant neurotic manifestation which could be interpreted as being an escape mechanism which would permit the patient to assume that the beloved mother was still alive. It is obvious here, too, that the first wife was a mother substitute, more frankly adopted than is usually the case.

The patient's whole history at the time that his wife left him is full of holes. He would remember, for instance, that he had a responsible job, but could not tell how much he had earned. He could, nevertheless, recall such usually forgotten facts as the employer's name and his fraternal affiliations. He rationalizes by saying that he was worrying at that time about his wife.

Several years later he came to Detroit and commenced living with a woman. No amount of urging could squeeze from him significant facts about this common-law relationship and his later forced marriage. He claimed that his mind was a blank for the year and a half preceding his trial, the period in which the murder was committed. There were no significant physical ailments.

The psychiatric examination indicated no blocking of the stream of thought, no conscious feelings of guilt, no delusional life. He seemed to be matter-of-fact about the situation and stated that his conscience was clear, for he did not remember the details of the crime. In the few cases of this type which I have seen this typical psychoneurotic escape mechanism does appear frequently.

Another and more recent case (Case No. 2) will serve to illustrate the mechanism in an even more satisfactory manner. The patient was a white woman, thirty-two years of age. Her case turned out to be most difficult. For instance, she showed no signs of a con-

ventional psychosis when seen. It was then found that the circumstances of the crime were as follows: One evening after being away a good part of the day the patient took her crippled child into the basement and shot him and herself. The child died, but she was taken to the hospital, where after a period of treatment she recovered.

In studying her case it was found that she had worried about the physical condition of the child for some time and had developed the psychoneurotic idea that the child could never be cured. Yet we learned from the attending physician that the mother had been told that there was a reasonable possibility of much improvement. She ignored this information in an obsessive manner and reacted as described above. Her basic endowment was found to be unstable, for after the crime she went into a depression because, as she said, she missed her child and not because she committed the crime. On one occasion she showed definite signs of mental disintegration, for she admitted that the dead child returned to her in her cell and sat in her lap. She insisted on the reality of this hallucination during one interview, but later claimed that it was only imagination.

Further investigation showed that at the time of her hospital treatment after shooting herself, she was, as one psychiatrist said, "a very sick woman," but he would not call her insane. All those who had contact with her at that time insisted that she acted queerly, could recognize no one, and forgot even the prosecutor from one day to the next — an unusual type of behavior.

In addition, she had a familial weakness, evidenced by her mother's instability and a suicide by a sister some years before. One definite psychoneurotic feature which is highly significant was her expression of a feeling of relief after the crime, indicating an expiative mechanism of some kind. Her crime and attempted suicide were, in part, a result of the cumulated pressure of her problems and, in part, a result of a pattern for escape of which she had been made aware by the sister's suicide. She was, therefore, more of a psychoneurotic than a psychotic, but under the law which has been quoted earlier, she could, by intelligent reasoning, be considered legally insane, for she was compelled by circumstances resulting from mental ill health to commit this crime. We might note a definite emotional instability. Toward the end of the examination and observation period she showed reasoning and emotional tendencies which an insanity commission thought were signs of an impending psychosis.

The third case is one of a young man who was brought into the Clinic after pleading guilty to murder in the first degree. His statement was that he had been carrying out a number of robberies with the other boys who were arrested with him and, on the occasion when he committed this murder, he decided that he would rob a grocery store alone. There was a girl customer ahead of him, and he waited until his victim had finished with her before he pulled out a revolver and demanded his money. He stated that the victim lunged at the revolver, attempted to get it away from him, and reached for a hatchet which was on the back of the counter. The patient then shot his victim.

He had a slight endocrine glandular condition. He was given a clean bill of health psychologically, for his I.Q. was 96. When we went into the case in some detail, we found that he was deeply attached to his mother. For instance, when asked about her, he said: "I know she is young and good-looking. I wish I was as smart." We also found that he had identified himself with his father, for he used the expression that he was "just like his father."

Further examination indicated that he had developed marked feelings of guilt, not only in regard to the present offense, but in regard to the emotional situation in his family. He told the examiner that he wished to be punished, although he did not realize that this was his way of expiating for his feelings of guilt in the sexual sphere and in the case of the present crime. We found in this example, then, a picture of a fellow who was neurotic and unstable, whose criminalistic tendencies were based upon his neurotic suggestibility and the fact that he was influenced by other boys, all of which drove him to robbery.

In conclusion, then, the statement might be made that, while neurotic murderers are few and far between, they present interesting clinical pictures. The influence of the neurosis may be noted in relationship to every angle of the crime. It may predispose toward the commission of the crime of murder. It may provide elements of escape from responsibility at the time of the murder, or it may enable the individual to escape from his problems caused by the crime. Finally, it may provide the means for the individual to try to make an escape from the consequences of his crime.

EGGS AND NATURAL NESTS OF THE EAST-
ERN RINGNECK SNAKE, *DIADOPHIS*
PUNCTATUS EDWARDSII *

FRANK N. BLANCHARD

DATA on the natural history of the ringneck snakes have been accumulated each summer, for a number of seasons, in the vicinity of the University of Michigan Biological Station, Cheboygan County, Michigan. Directly after my arrival in late June I visit a favorite collecting site in Emmet County and collect all the snakes I can find. Almost all these are females with eggs to be laid. They are taken to the laboratory and segregated in small cages until their eggs have been deposited, an interval rarely longer than three weeks. There can be no doubt that bringing snakes to the laboratory postpones deposition of the eggs. This procedure, however, gives accurate data on the number of eggs in a complement, on their dimensions, and on the relation between the length of the female and the number laid.

All the ringneck snakes brought to the laboratory are measured and their scutellation is recorded. The length taken is the average of numerous (6 to 10) measurements made separately. The snakes are then marked by the method described in 1933 (Blanchard and Finster), and, after the females have laid their eggs, all the snakes are returned to the locality on Big Stone Bay in Emmet County described in an earlier report (Blanchard, 1926, pp. 280-281). The young snakes hatched from the eggs are also returned here, so that the supply is undiminished. Each season a number of snakes released in some previous year are recaptured.

Females of this species with unlaid eggs are not found after early July (July 4 is the latest date; see Table I), and, oddly enough, after this time spent females are also less often found than are males. Before the time of egg laying males are infrequently seen, whereas

* Contribution from the Biological Station and the Department of Zoölogy, University of Michigan, supported by grants from the Faculty Research Fund.

toward midsummer they appear to be numerous. For records of eggs in relation to the females that lay them, early collecting is essential; for nests, one must search from early July to middle August, but it takes a great deal of hunting to assemble many records of natural nests, since most of the apparently desirable sites contain no eggs.

Nearly all the nests found have been in decaying logs, large or small, in sunny situations. The eggs lie beneath a hard crust, or in the rotted interior, if the outside is hard, and on the sunny side. Only logs in the vicinity of undisturbed woodland, coniferous or hardwood, are used. The most profitable hunting grounds have been the Great Lakes beaches in the vicinity of such woodlands where the beaches are low and not extensive, and bear a good deal of driftwood (Pl. LIII, Fig. 1). Hunting on stony beaches, beaches with sand dunes, and beaches with an excessive amount of old wood, such as those near old sawmill sites, is not profitable.

NESTS

A few natural nests of the eastern ringneck snake have already been reported (Blanchard, 1930, pp. 4-5). One of these records was of a nest of 20 eggs, which clearly proves that more than one female may contribute to the eggs in a nest. Records accumulated in Cheboygan and Emmet counties since 1929 do not essentially alter that understanding, but they do show much more clearly the general situation with regard to the nests of this species. Following is a chronological enumeration of those subsequently found:

1. July 2, 1930. A nest of 48 eggs was discovered in a large log (13 feet long and $1\frac{1}{2}$ feet in diameter) on the beach at Big Stone Bay, Emmet County. The eggs lay in the soft, rotted wood just under the inch-thick, hard outer shell of solid wood on the upper side of the log (Pl. LIII, Fig. 2). In the vicinity of the eggs, but not at the nest, were seven large female ringneck snakes, and under a board on the sand near by was one more. Of the eight females, only one had laid her eggs. It may have been the one under the board, but since this snake was bagged with the other seven its identity was lost before the observation was made. If female ringneck snakes lay on the average $3\frac{1}{2}$ eggs apiece (a mean derived from 202 sets), then about 14 females contributed to the accumulation of

the 48 eggs. If the other seven females had added their eggs to the mass, there would have been about 72 eggs in the log. This nest had been used before, as old eggshells of at least two previous seasons attested.

Since of about 22 egg-laying ringneck snakes (including those that had laid their eggs and gone) only one spent individual was found, it appears that a female of this species is likely to occur in a suitable site for egg laying only preceding oviposition; that after that event she soon leaves. This corresponds with collecting experience from late June to early July, when females bearing eggs are relatively easy to find under cover in superficial situations. Males are usually scarcer at this season. But on this very day, July 2, 1930, not far from the nest of 48 eggs a small log, ten feet long, contained 15 large ringneck snakes and one moderate-sized milk snake; and of the 15 ringnecks, 14 were mature males and one was a juvenile female. The log was dry all through, and its interior was complexly tunneled with ant runways. It was by chopping and prying into these tunnels that the snakes were located. It is notable that there were neither spent nor pregnant females in this log. It was too dry for a nesting site. No old eggshells were found, but old skins and fragments of skins were strewn all through it. It is not likely that any of the snakes were there to feed, for there was nothing recognizable in the stomachs of these ringneck snakes, and nearly all were empty. The milk snake had recently fed on one or two masked shrews. If he had been in the log to feed, there is no reason why he should not have been eating ringneck snakes. It thus appears that this log was used only for resting purposes. But there were no egg-laying females present. Those preparing to lay were probably seeking suitable places; those that had laid were somewhere else; and the little snakes were also somewhere else.

2. July 9, 1930. A nest of 4 eggs was located in a crevice of a large rotted log on the beach west of the ringneck "colony" on Big Stone Bay. A mature male was close to the eggs, and two other large males were in the same log. This is in accord with other experience, that after the eggs are laid more male than female ringneck snakes will be found.

3. July 16, 1930. A nest of 6 eggs, one spoiled and eaten (or rotted away to a shell), were found in a rotted log on the beach west of Cecil, at Cecil Bay.

4. Aug. 5, 1930. A set of 2 eggs was found in a log at Big Stone Bay considerably east of the ringneck "colony." About a foot distant from these eggs, in the same log, was a group of 3 eggs. The log was an old telephone pole with hard center, an outer crust, and a rotted section between. It lay on the grass in an opening about 15 feet from the edge of the beach.

5. July 17, 1931. A nest of 7 eggs was found in a rotted log on the beach at Big Stone Bay. Although these eggs were all together, they may have represented three complements, to judge by size and shape.

6. June 29, 1932. On the beach at Big Stone Bay in one small log, channeled with ant tunnels, there were five nests, of 10, 10, 8, 4, and 1 eggs, respectively, and 16 large females bearing eggs. The nest of 10 eggs had shells of two previous seasons. There were two other nests of old shells of the year before and one of shells at least two years old. If these 16 females had laid their eggs in this log (as it may be assumed they would have), it would then have contained about 89 eggs of this season in all. Plates LIV and LV show this log in various stages of the destruction necessary for determining its contents, Figure 1 of Plate LIII illustrating the final stage.

7. July 29, 1932. A nest of 6 eggs was found in the lower end of a rotted stump that lay on its side in an aspen opening near Maple River in Cheboygan County. One egg looked spoiled, the others good.

8. Aug. 4, 1932. A nest of 2 old eggshells was found in a log on the beach at Bois Blanc, an island east of the city of Cheboygan. They were probably of the previous year.

9. Aug. 13, 1932. Three eggs and 2 shells were found together in a rotted log near Mud Lake, Cheboygan County. The log, as usual, was exposed to the sun.

10. July 4, 1933. A set of 3 good eggs and one shriveled egg lay in sand under a log on the Big Stone Bay beach (Pl. LVI, Fig. 1). This is the only instance of eggs of this species being found under wood in contact with the ground, except for the shells described under No. 12.

11. July 27, 1933. Near the top of a large log embedded in beach sand at Cecil Bay there was a group of 8 eggs. Three of these were pale yellow (indicative that they had been recently laid), constituting one set; the other 5 probably comprised another.

Embedded in sand and rotted wood below these 8 eggs was a group of 5 yellow eggs, and 8 inches to the left of these was a single egg.

12. Aug. 9, 1933. A set of 5 eggshells of a previous season was found on the sand under a log on the beach at Big Stone Bay.

13. July 4, 1934. Four nests of eggs and 7 females were found in a large log embedded in sand on the beach at Big Stone Bay. Most of the log was solid, but it was rotted and channeled a little at each end. In one end were 5 females and 3 nests of eggs: one of 4 eggs; one of 3; and one of 2 eggs. One of the 5 females was near a set of eggs and her body was badly shrunk, as if she had just deposited her eggs. Also in this end of the log was one eggshell of a previous season.

In the other end of the log there were 2 females, one set of 4 fresh eggs, and at least 9 old shells.

14. July 18, 1934. From a punky piece of rather dry, old log on the beach at Big Stone Bay a *Diadophis* egg fell out as the log was turned. Another egg was shaken from the same place. Then a nest of 5 eggs of one set and a separate egg were easily located. On breaking off a chunk of the log a large nest of eggs was disclosed. Cracking off another chunk revealed four more groups of eggs — two of 6, one of 2, and one of 4 — and several old shells. Some of the eggs were too dry, and perhaps were spoiled. This season's eggs totaled 55 in this one small log. Sets of 6, 4, 4, 3, 2, and 2 eggs could be recognized, but the remaining eggs were not resolvable into sets. (See Pl. LVI, Fig. 2; Pl. LVII, Figs. 1-2.) There were no ants in this log.

15. July 25, 1934. In the end of a beach log at Big Stone Bay there were 5 fresh eggs together, 8 shells of the previous year, and 2 adult male ringneck snakes.

16. July 24, 1935. Three eggs were found in the end of a beach log at Big Stone Bay.

From these accounts and the summary of them given in Table I it may be concluded that the female ringneck snakes commonly lay their eggs in logs exposed to the sun; that single favorable logs may be the resort of many females; and that such logs may be used year after year. On account of their search for nesting sites females are relatively easy to find before their eggs are laid. Very soon after laying the eggs the females desert the nesting sites and retire to

situations less accessible to collectors. They are then harder to find than are the males. This relative scarcity of females extends through midsummer. The facts that males are seldom found in the nesting logs and that, after egg laying, the females are not often found there either, show that the logs selected for nests are chosen for that purpose alone.

TABLE I

SUMMARY OF NUMBERS OF RINGNECK SNAKES AND THEIR EGGS
FOUND IN LOGS USED FOR NATURAL NESTS

Date	Number of eggs in log	Number of snakes in same log with eggs		
		Females		Males
		With unlaidd eggs	Spent	
June 29	33	16	..	..
July 2	48	7	1	..
July 4	4	..	..	..
July 4	15	6	1	..
July 9	4	..	..	3
July 16	6	..	..	..
July 17	7	..	..	..
July 18	55	..	..	..
July 24	3	..	..	..
July 25	5	..	..	2
July 27	14	..	..	..
July 29	6	..	..	..
Aug. 5	5	..	..	..
Aug. 13	3	..	..	..

EGGS

Records on 202 sets of eggs show a variation of from 1 to 7 in a complement. Three and 4 are the commonest numbers; 2 and 5 are less common; and 6, 1, and 7 are relatively unusual. These facts are expressed in the histogram, Figure 12.

The average number of eggs produced per female, based on all 202 sets recorded, is 3.5, but within the ten seasons 1925 to 1935 (except 1928), the average has varied from 2.77 to 4.05. Only two of these seasons, however, provided enough records for a fair comparison of egg production between different years. For 1932 and 1935 the averages are 4.03 and 3.36 eggs per female, respectively,

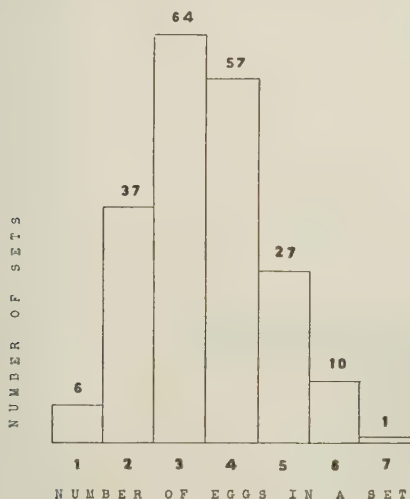


FIG. 12. Numbers of eggs in 202 total complements of the eastern ringneck snake. The mean of these records is 3.5 eggs per female

based on 40 and 44 specimens. The difference between these two means, 0.67, contains its probable error 3.7 times. From this it is perhaps safe to conclude that there may be a real difference between some seasons in the reproductive potentiality in this species.

The number of eggs produced bears a certain relationship to the length of the female snake, as may be seen in Figure 13. The coefficient of this correlation is 0.61 ± 0.03 . Instances of the laying of a single egg are confined to females less than 365 mm. long. The production of only 2 eggs is common in females of 380 mm. or less. Three eggs in a set is usual only in females from 360 to about 400 mm. long. Four eggs are produced by females of this same size and up to 440 mm. Laying of 5 eggs is nearly confined to females over

400 mm. in length, and of 6 is definitely so. There is only a single record of as many as 7 eggs being laid by one female, and they were produced by a snake 425 mm. long.

The largest captive female that laid eggs was 507 mm. in length. Her relatively small complement, 3, may be a feature of old age.

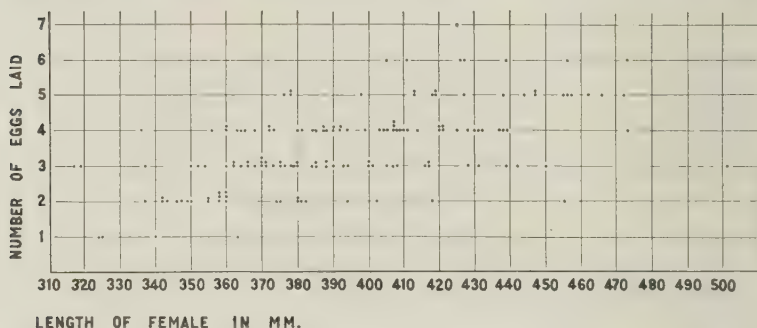


FIG. 13. Relation between length of female and number of eggs laid. Each dot represents one set of eggs and the length of the female that laid it

The smallest egg-bearing female was 317 mm. long. She laid 3 eggs. However, a specimen only 300 mm. long collected near Ann Arbor, in southern Michigan, also laid 3 eggs.

Since the egg-laying record of the same female in different years may be of interest, I have assembled in Table II such data as have been accumulated.

From a perusal of this table it appears that individual females tend to lay about the same number of eggs from year to year. In only one of those listed in the table (No. 16) was the variation as much as 2 eggs after one year. In No. 7 there was a 2-egg variation after five years. Nos. 1 and 2 hardly count, since they were immature when first captured. It is probably significant that the decreases in number of eggs produced were nearly confined to the longer and, therefore, older, females. Only one shorter than 400 mm. laid *fewer* eggs in a later year, and only one longer than 400 mm. laid *more* eggs in a later year. (No. 7 may be disregarded in this consideration, since the interval was so long, i.e. five years.) This may be, then, indicative of decreased egg production in the older females. Observe that a female 507 mm. long laid only 3 eggs (Fig. 13).

TABLE II

RECORDS OF THE NUMBERS OF EGGS LAID BY THE SAME FEMALE IN DIFFERENT YEARS, ARRANGED IN ORDER OF LENGTH OF FEMALES AT THEIR EARLIER MEASUREMENTS

Number of record	Year of laying	Length of female in mm.	Number of years since previous record	Number of eggs deposited	Change in number of eggs		
					Increase	No change	Decrease
1	1932	243		0			
	1935	342	3	2	+		
2	1931	303		0			
	1933	347	2	2	+		
3	1932	362		3			
	1934	375	2	3		+	
4	1932	364		4			
	1934	373	2	4		+	
5	1934	368		4			
	1935	372+	1	3			+
6	1932	370		3			
	1933	381	1	4	+		
7	1927	380±		2			
	1932	420±	5	4	+		
8	1932	420±		4			
	1934	429±	2	3			+
9	1930	392		4			
	1932	419	2	5	+		
10	1932	398		5			
	1933	403	1	4			+
11	1925	400		3			
	1926	400	1	3		+	
12	1932	402		4			
	1933	411	1	4		+	
13	1933	409		4			
	1934	442	1	3			+
14	1933	409		4			
	1934	417	1	3			+
15	1932	411		6			
	1933	427	1	5			+
16	1926	439		5			
	1927	439	1	3			+
17	1932	439		6			
	1934	447	2	5			+

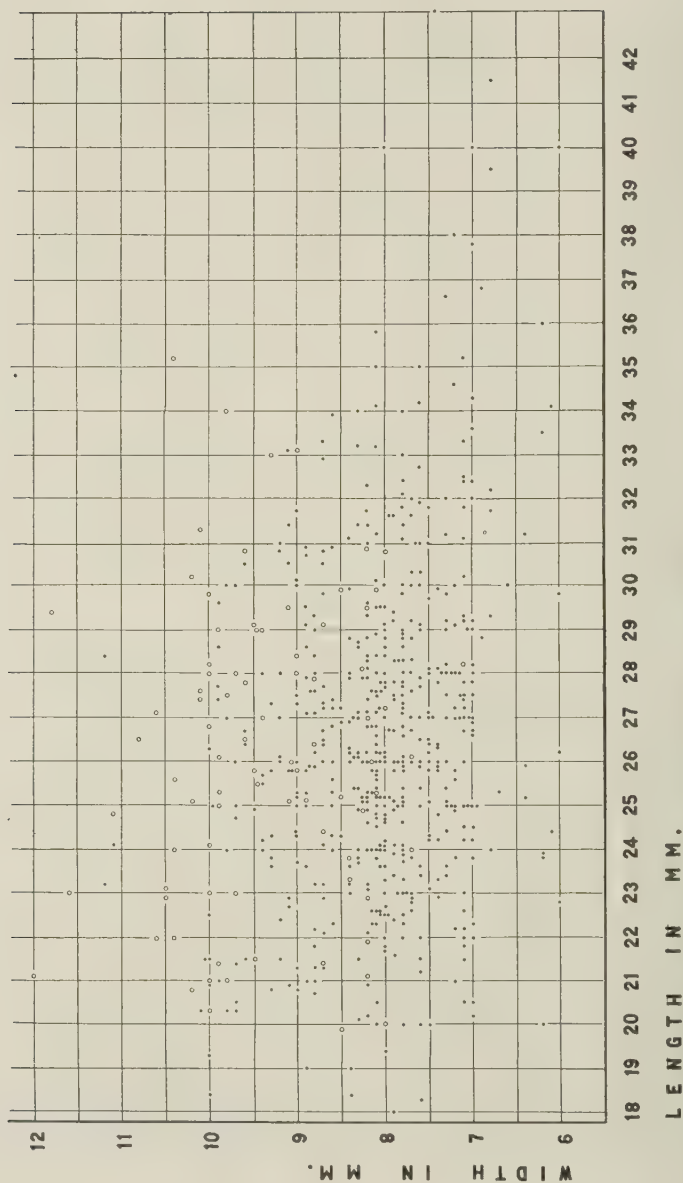


FIG. 14. Dimensions of eggs of eastern ringneck snakes. The position of each dot expresses the length and the width of one egg. Solid circles represent fresh eggs; hollow circles, eggs collected in field nests late in the season after their natural swelling had occurred (Blanchard, 1926, p. 283)

Measurements of eggs show extremes of length from 18.0 to 43.0 mm. and of width from 6.0 to 12.4 mm.; but the great majority of the eggs fall within length limits of 22 and 32 mm. and width limits of 7 and 8.5 mm. and, less frequently, up to 10 mm. The extremely long eggs are all slender (with the exception of the one widest egg), and the unusually wide ones are mostly rather short. These facts are all graphically expressed in Figure 14.

Within any single clutch the eggs tend to be uniform in size, proportions, and appearance. Small clutches are likely to be composed of long eggs and large clutches of short eggs. Examples of these relationships are given in Table III.

TABLE III

SAMPLE CLUTCHES OF EGGS, WITH THEIR MEASUREMENTS IN MILLIMETERS, SHOWING THE TENDENCY TO UNIFORMITY IN DIMENSIONS OF THE EGGS OF A SET—LONG EGGS IN SMALL CLUTCHES AND SHORT EGGS IN LARGE CLUTCHES

<i>Length of female</i>	<i>Measurements of eggs</i>		<i>Length of female</i>	<i>Measurements of eggs</i>	
	<i>Length</i>	<i>Width</i>		<i>Length</i>	<i>Width</i>
378	23.6	8.0	456	25.0	7.3
	23.6	7.3		23.4	7.6
	23.0	7.8		21.5	7.6
	22.6	7.7		23.6	7.6
	22.3	7.0		26.0	7.4
418	26.0	8.0	425	22.3	8.6
	22.0	8.0		21.6	7.9
	27.0	8.0		19.4	8.0
	24.0	8.1		19.0	8.4
	22.6	8.1		19.1	8.9
447	21.5	9.6	381	18.0	7.9
	22.5	10.0		18.4	8.4
	21.5	10.0		34.6	7.2
	20.3	10.1		36.6	7.3
	20.5	9.7		34.2	7.6
				29.7	7.5

SUMMARY

In northern Michigan the eastern ringneck snake lays its eggs in late June and very early July.

The female deserts her eggs almost immediately after depositing them.

Some nests contain the eggs of only one female, but often from

a few to many females lay in the same nest, and there may be many nests in one log.

Logs lying in the sun, hard on the outside and rotted within or containing cavities, are, so far as observations go, the favorite nesting sites of this species. Such logs may be resorted to for egg laying year after year.

This snake may lay from 1 to 7 eggs, but 3, 4, and 5 are the only common numbers. The average of 202 sets is 3.5 eggs per female.

The minimum recorded length of a female laying eggs in northern Michigan is 317 mm. (but a 300-mm. specimen at Ann Arbor laid eggs); the maximum length is 507 mm.

The number of eggs laid bears a general relation to the length of the female. The larger females lay more eggs, but there seems to be a tendency for very old (large) females to lay fewer eggs.

The eggs vary in length from 18.0 to 43.0 mm. and in width from 6.0 to 12.4 mm., but the great majority of the eggs fall within the length limits of 22 and 32 mm. and the width limits of 7.0 and 8.5 mm.

Within any single clutch the eggs tend to be uniform in size, proportions, and appearance.

UNIVERSITY OF MICHIGAN

LITERATURE CITED

- BLANCHARD, FRANK N. 1926. Eggs and Young of the Eastern Ring-neck Snake, *Diadophis punctatus edwardsii*. Pap. Mich. Acad. Sci., Arts and Letters, 7 (1925): 279-292, pls. 13-19.
- 1930. Further Studies of the Eggs and Young of the Eastern Ring-neck Snake, *Diadophis punctatus edwardsii*. Bull. Antivenin Inst. Am., 4: 4-10.
- AND FINSTER, ETHEL B. 1933. A Method of Marking Living Snakes for Future Recognition, with a Discussion of Some Problems and Results. Ecol., 4: 334-347.

PLATE LIII



FIG. 1. Beach at Big Stone Bay, Emmet County, Michigan, favorable for the finding of ringneck snakes and their eggs

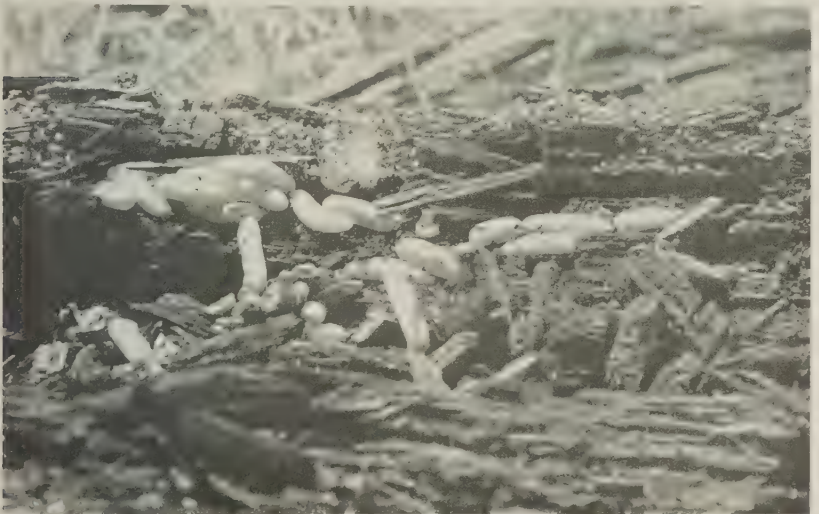


FIG. 2. Nest of 48 eggs of the ringneck snake discovered July 2, 1930, at Big Stone Bay. The hard top of the log has been removed, exposing the eggs just as they lay in the loose rotted portion. Empty eggshells of previous seasons may be seen at left center

PLATE LIV



FIG. 1. Log containing five nests discovered June 29, 1932, showing one nest revealed by the first split. The ax is regularly used in this kind of work



FIG. 2. A nest of six eggs in the log shown above

PLATE LV



FIG. 1. Two more nests in the log shown in Plate LIV



FIG. 2. Another nest and eggshells of a previous season
in the log shown above and in Plate LIV

PLATE LVI

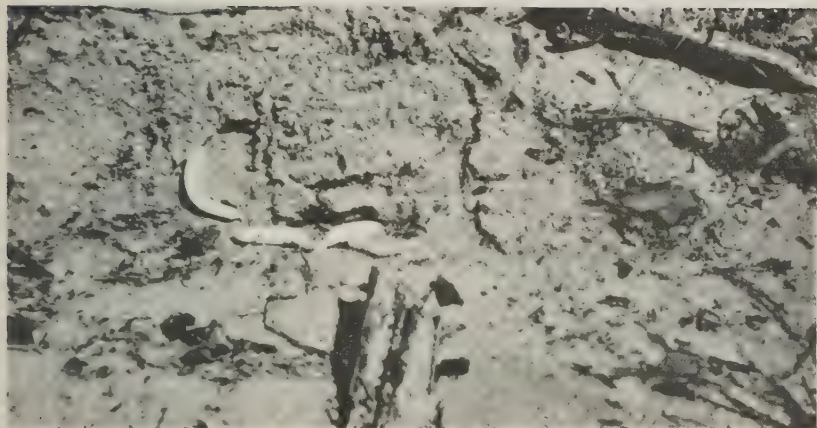


FIG. 1. The only instance in which fresh ringneck eggs have been found on the sand under a log



FIG. 2. Log containing 55 eggs of ringneck snake, found July 18, 1934. When the piece of wood shown slightly out of focus at lower center was removed the two rows of eggs shown in Figure 1 of Plate LVII were revealed. None of the eggs of this or other nests were disturbed before photographing

PLATE LVII

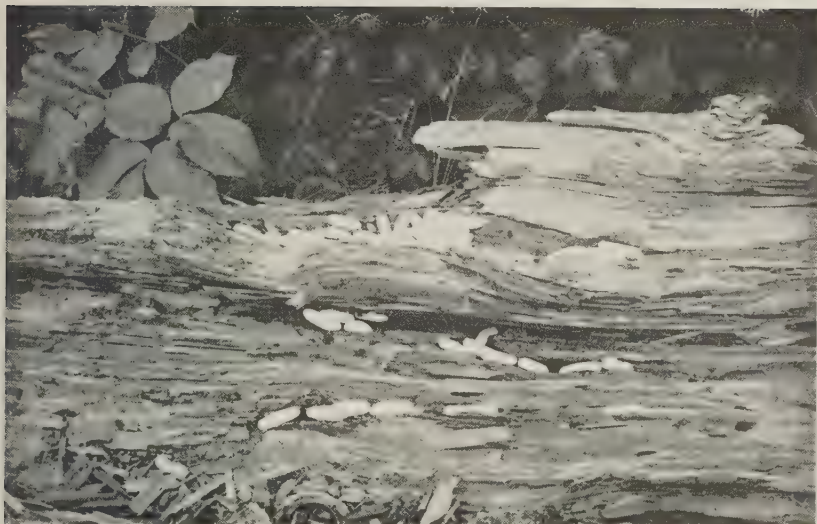


FIG. 1. The log shown in Figure 2 of Plate LVI, opened further, revealing four more sets of eggs in narrow channels

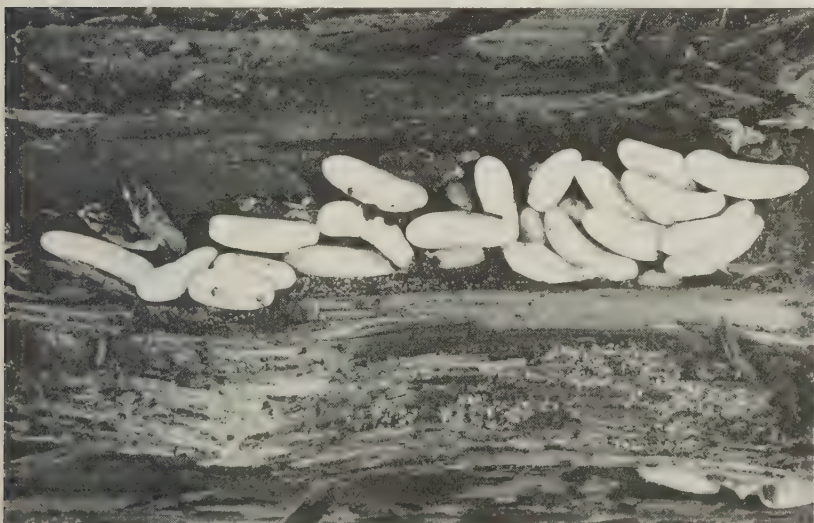


FIG. 2. The log illustrated above and in Figure 2 of Plate LVI, showing the largest of the egg groups and numerous empty shells of a previous year

CONTRIBUTIONS TO TEXAN HERPETOLOGY

V. SPINY AND SCALY LIZARDS (*SCELOPORUS*)

CHARLES E. BURT

THE data presented in this series were gathered during the years 1930-36. The collections are largely in the United States National Museum, and all the specimens in that institution have been studied critically. The ten Texan *Scelopori* are diagnosed by the following key:

1. A conspicuous black collar or blotch in front of shoulder 5
1. No conspicuous black collar or blotch in front of shoulder 2
2. Usually 37 or fewer than 37 scales from occiput to base of tail; adults often large, over 90 mm. Mexican scaly lizard. Rio Grande Valley and most of Texas, except extreme east and Panhandle
S. spinosus Wiegmann
2. Usually more than 37 scales from occiput to base of tail; adults smaller .. 3
3. Fewer than 48 scales from occiput to base of tail 4
3. More than 48 scales from occiput to base of tail 8
4. Back distinctly striped, usually with spots or nonundulate markings.
Prairie spiny lizard. Texas, north and west of mouth of Rio Grande
S. undulatus consobrinus Baird and Girard
4. Back not distinctly striped, usually with wavy dark brown crossbars.
Eastern spiny lizard. Texas, north and east of mouth of Rio Grande
S. undulatus undulatus (Latreille)
5. A black blotch that is confined to the lateral region or rapidly narrowed dorsally 7
5. A broad black collar with parallel edges that unite or approach dorsally 6
6. More than 51 scales from occiput to base of tail. Ornate spiny lizard.
Lower Rio Grande *S. ornatus* Baird
6. Fewer than 51 scales from occiput to base of tail. Mexican scaly lizard.
Rio Grande Valley, north to central Texas
S. torquatus poinsettii Baird and Girard
7. External parietal and frontoparietal plates separated from supraoculars by a series of small granules..... 8
7. External parietal and frontoparietal plates in contact with large supraoculars. Desert scaly lizard. Trans-Pecos region
S. clarkii clarkii Baird and Girard

- | | |
|---|---|
| 8. Fewer than 69 scales from occiput to base of tail; throat often with blue markings | 9 |
| 8. Sixty-nine or more than 69 scales from occiput to base of tail; throat often variegated with black and white. Small-scaled spiny lizard. Lower Rio Grande | <i>S. couchii</i> Baird |
| 9. More than 50 scales from occiput to base of tail | 10 |
| 9. Fewer than 50 scales from occiput to base of tail | 2 |
| 10. Dorsolateral stripes absent or very faint; center of lateral belly patches blue | 11 |
| 10. Dorsolateral stripes distinct; center of belly patches pink. Texan rose-bellied spiny lizard. Lower Rio Grande north to Central Texas | <i>S. variabilis marmoratus</i> (Hallowell) |
| 11. Belly patches of males strongly emarginated with black or deep indigo, at least posteriorly; body often gray or olivaceous above. Pecos spiny lizard. Upper Rio Grande and Big Bend area .. | <i>S. merriami</i> Stejneger |
| 11. Belly patches of males weakly emarginate or not bordered at all by dark markings; body brown. South Texan spiny lizard. Lower Rio Grande | <i>S. disparilis</i> Stejneger |

As a group, the spiny and the scaly lizards show definite climbing instincts. When trees are available they are frequently seen on the trunks or among the branches, but in more barren places they are forced to become rock climbers instead. Not possessing the speed of race runners (*Cnemidophorus*) or sand lizards (*Holbrookia*), they rely more upon craftiness in seeking concealment. The Mexican scaly lizard sometimes wedges its body into such small rock crevices that it cannot be reached with forceps, even when it is in plain sight. The smaller spiny lizards are less protected when they exhibit the same reaction by wriggling under bark; in fact such behavior often aids materially in their capture.

Sceloporus clarkii clarkii Baird and Girard

This desert scaly lizard has invaded Texas from the west, occurring at least at Boquillas, Brewster County, and El Paso, El Paso County.

Sceloporus couchii Baird

This species has a remarkably fine dorsal scutellation. There are 73 scales from the occiput to the base of the tail in the only Texan specimen at hand (U. S. N. M. No. 14741, San Diego, Duval County, type of *Lysoptychus lateralis* Cope). Some specimens from Mexico have as many as 82 scales in this count. *S. undulatus con-*

sobrinus sometimes approaches *couchii* in coloration, but not in scalation. The Mexican types of *couchii* have smooth throats, but the preserved Texan specimen mentioned above displays a transverse gular fold which Cope noticed in 1888 and used as the basis for the description of a new genus and species; even a gentle pressure on the snout of this "*lateralis*" removes the neck fold, which may have been formed during killing and preservation.

Sceloporus disparilis Stejneger

The type and four paratypes of this species are all from Lomita Ranch, about 6 miles north of Hidalgo, Hidalgo County.

Sceloporus merriami Stejneger

This species occurs in abundance about rock cliffs in Val Verde County, and it has been collected at Boquillas, Brewster County, to the westward. On August 27, 1935, many specimens were observed in the picturesque Castle Canyon, about 17 miles southeast of Comstock. The Pecos spiny lizard is an agile climber and prefers rocks to trees. At the same place only *S. spinosus* was found in trees below the canyon walls.

Sceloporus spinosus Wiegmann

An examination of the type of *floridanus* and of other southeastern spiny lizards indicates that in the Pensacolan area of Florida dwells a poorly differentiated subspecies of *undulatus* (*S. u. floridanus*) and that in the Gulf strip between Florida and Texas only typical *undulatus* occurs. Cope (1885, p. 398) went even further than this and considered *floridanus* a synonym of *undulatus*. The true *spinosus* stock appears to be distinct from *undulatus*, and it has entered Texas from Mexico.

Spinosus is typically diurnal and arboreal, spending its life in the vicinity of woods, where it climbs about trees, old logs, large rocks, and brush piles. It spends the night under the protection of bark, flat rocks, or large pieces of tin. Continued experience has indicated that, if the latter shelter is present, it is very likely to be used during the cooler part of the day, for it seems to offer an advantage to the lizard in "warming up" in the morning.

Young specimens of *spinosus* are apt to be confused with *undulatus*, since the two agree in size and in general appearance. A young

example of *spinosus* taken in Falls County on April 6 measured 38 mm. in body length and 55 mm. in tail length. A large female collected in Dallas County on April 11 had 23 eggs in the abdominal cavity, 12 on the right side, and 11 on the left.

County	Locality	Date	Collector
Bexar	Somerset	Jan. 20, 1927	Kirn, A. J.
Brown	3 mi. W. Brownwood	July 27, 1931	Smith, H. M.
Calhoun	Indianola	.....	Graham, J. D.
Callahan	Putnam	April 18, 1926	Kirn
Cameron	Brownsville	May, 1866	Perry, I.
Concho	.....	Sept. 10, 1893	Lloyd, W.
Dallas	5 mi. SE. Dallas	April 11, 1931	Burt, C. E.
Duval	San Diego	.....	Taylor, W.
Ellis	8 mi. NE. Midlothian	Oct. 31, 1930	Burt
El Paso	El Paso	.....	Clark, J. H.
Erath	12 mi. NE. Stephensville	March 17, 1934	Burt
Falls	1 mi. W. Marlin	April 6, 1931	Burt
Fayette	Rutersville	.....	Forshey
Grayson	1 mi. N. Howe	March 22, 1936	Burt
Guadalupe	Seguin	Nov. 8, 1904	Bailey, V.
Hays	U. S. Fish Commission Grounds, San Marcos	.....	Leary, J. L.
Hidalgo	McAllen	Aug. 30, 1916	Streeter, D. D.
Hood	5 mi. S. Paluxy	March 17, 1934	Burt
Jack	Bryson	April 19, 1931	Burt
Jim Wells	8 mi. NE. Alice	Aug. 25, 1935	Burt
Karnes	Runge	Aug. 29, 1905	Howell, A. H.
Kendall	3 mi. N. Waring	Sept. 3, 1935	Burt
Kerr	3 mi. W. Comfort	March 7, 1931	Sanders, O.
Kinney	Fort Clark	.....	Potter, J. A.
McLennan	Mart	Aug. 20, 1927	Adams, F. M.
Nueces	Corpus Christi	Oct. 20, 1891	Lloyd
Palo Pinto	3 mi. E. Palo Pinto	March 29, 1931	Burt
Smith	5 mi. W. Arp	April 2, 1932	Sanders
Sutton	26 mi. SE. Sonora	May 15, 1922	Babcock, A. G.
Tarrant	Fort Worth	March 29, 1931	Burt
Tom Green	San Angelo	June 8, 1894	Lloyd
Travis	Austin	.....	Patterson, J. T.
Val Verde	Castle Canyon 17 mi. SE. Comstock	Aug. 27, 1935	Burt
Victoria	Victoria	Sept. 11, 1906	Howell

Sceloporus torquatus poinsettii Baird and Girard

These handsome lizards are characteristic inhabitants of rock-walled canyons. The two cotypes in the national collection are from Rio San Pedro (= Devil's River), Val Verde County.

County	Locality	Date	Collector
Brewster	20 mi. S. Alpine	Aug. 28, 1935	Burt, C. E.
Duval	San Diego	.....	Taylor, W.
Jeff Davis	9 mi. NE. Fort Davis	June 18, 1933	Hoyle, L.
Maverick	Eagle Pass	1890	Lloyd, W.
San Saba	Mouth of Brady Creek	July 23, 1931	Smith, H. M.
Terrell	9 mi. W. Dryden	Aug. 27, 1935	Burt
Val Verde	East Painted Cave	Sept. 3, 1890	Lloyd
Webb	Laredo	.....	Butcher, W.

Sceloporus undulatus consobrinus Baird and Girard

The status of the Middle-Western lizard under discussion has long been in doubt, as Jones (1926) has shown in giving it the name *thayerii*, as opposed to the long-recognized *consobrinus*, using as his criterion a common recognition of the synonymy of the two forms and an apparent priority in the publication date of the former name. However, a diagnosis of *thayerii* (as such) in comparison with *undulatus* was not presented by either Baird and Girard or Jones.

The three existing types of *thayerii* are from Indianola, Calhoun County, Gulf Coast of Texas (U. S. N. M. No. 2887). Other specimens of the lizard were mentioned in the original description as occurring at "San Antonio, El Paso, and as far west as the province of Sonora." If one uses the standard characters incorporated in the key given above for the separation of *undulatus* and "*consobrinus*" in Texas, it is found that specimens from Indianola and the surrounding country identify as true *undulatus*. To the west of this area a color variant with dorsal spots in place of undulating crossbars occurs in company with young specimens of *spinosus* (these latter lizards resemble *undulatus* so closely that some confusion of the two might easily have resulted). However, in the original description of *thayerii*, Baird and Girard (1852) specifically mentioned having seen both "transverse undulating bands" and "series of small patches" of brown or black on the back of this species. Thus it appears that *thayerii*, as conceived originally by its describers, is a composite form. The types of *thayerii* from Indianola are in a poor state of preservation, but one specimen exhibits a distinct series of undulating crossbars on the back, thus leaving no doubt as to its colorational identity with *undulatus*. After considering all the known facts in the case, and in particular the character of the existing cotypes, it seems best and most logical to relegate *thayerii* to

the synonymy of *undulatus*. Contrary to Jones (1926, p. 3), it appears that Baird and Girard may have recognized the differences between *thayerii* and the lizard that they later described as *consobrinus*, instead of having "failed to notice their great similarity," for, as noted above, both types of coloration were mentioned in the original description of *thayerii*, while only the spotted western type was specified later for *consobrinus* in its original diagnosis. Thus, through supplemental analysis, it appears that Baird and Girard may have ultimately limited or restricted their conception of *thayerii* to the undulated population of *undulatus* as represented by individuals along the extreme southwestern border of the range in Texas.

County	Locality	Date	Collector
Brewster	Boquillas	May 28, 1901	Oberholser, H. C.
Brooks	5 mi. N. Encino	April 4, 1931	Burt, C. E.
Cameron	Santa Rosa	Sept. 22, 1891	Lloyd, W.
Comanche	Bibb	.....	Jaynes, R. T.
Cooke	Gainesville	.....	Ragsdale, G. H.
Duval	San Diego	.....	Taylor, W.
Eastland	4 mi. N. Rising Star	March 17, 1934	Burt
El Paso	El Paso	July 15, 1902	Hurter, J.
Erath	4 mi. NE. Dublin	March 17, 1934	Burt
Fisher	Grady	April 30, 1901	Shepherd, T. M.
Hudspeth	Fort Hancock	1893	Mearns, E. A.
Jeff Davis	8 mi. NW. Toyahvale	June 18, 1933	Hoyle, L.
King	1 mi. S. Grow	June 12, 1933	Hoyle
San Saba	2 mi. S. San Saba	March 8, 1931	Burt
Val Verde	Langtry	Jan. 28, 1890	Bailey, V.
Webb	Laredo	.....	.....

Sceloporus undulatus undulatus (Latreille)

This is the characteristic spiny lizard of the east Texas timber belt, where it has been found in grass about rock piles, brush, and logs, as well as under or on flat pieces of tin, flat rocks, and the loose bark of stumps and logs. A female taken in Sabine County on May 10 was found to be carrying eggs in the abdominal cavity.

Ortenburger and Freeman (1930, p. 175) have determined the line of intergradation of the allied subspecies *S. u. undulatus* and *S. u. consobrinus* as the 97th meridian in Oklahoma. This same line separates the two populations in Kansas, and the existence of a wide belt between their ranges in the eastern part of the state (from which specimens of *Sceloporus* are not available) suggests the absence of intergradation in the northern part of the range. The present study

indicates that the region of the 97th meridian is the general line of intergradation in Texas, although in the south specimens of *undulatus* with prominent dark brown dorsal crossbars have been taken in Goliad County, which is slightly west of this line. On the 97th meridian in northern Texas intergradation is common, the dorsal crossbars so characteristic of *undulatus* becoming reduced and the yellow spots on the sides better developed to offer an approach to the western *consobrinus*. Texan specimens of *consobrinus* tend to show less concentration of the dorsal dark brown pigment than more northern ones — this alone suggesting a lesser differentiation from *undulatus* in the more southern section of the race.

County	Location	Date	Collector
Anderson	Neches River, 14 mi. E. Palestine	Nov. 24, 1891	Evermann, B. W.
Angelina	4 mi. SE. Wells	May 9, 1931	Burt, C. E.
Bowie	1 mi. S. Maud	May 2, 1931	Burt
Calhoun	Indianola	.....	Clark, J. H.
Cass	8 mi. N. Linden	May 2, 1931	Burt
Colorado	Columbus	Nov. 14, 1904	Bailey, V.
Comal	2 mi. SW. New Braunfels	April 2, 1931	Burt
Goliad	5 mi. NE. Fannin	April 5, 1931	Burt
Grayson	3 mi. N. Denison	March 22, 1936	Burt
Gregg	2 mi. NW. Longview	March 28, 1931	Burt
Hardin	7 mi. SE. Kountze	July 6, 1934	Burt
Henderson	Eustace	July 7, 1934	Burt
Lamar	Arthur City	June 16, 1892	Bailey
Marion	3 mi. N. Jefferson	May 2, 1931	Burt
Nacogdoches	West bank of Attoyac River, about 1 mile east of Chireno	May 10, 1931	Burt
Robertson	Wheelock	.....	Kellogg, F.
Rusk	4 mi. S. Mt. Enterprise	June 17, 1934	Burt
Sabine	2 mi. S. Brookeland	May 10, 1931	Burt
Trinity	5 mi. NW. Groveton	July 6, 1934	Burt
Tyler	Hillister	July 6, 1934	Burt
Victoria	2 mi. SW. Inez	April 5, 1931	Burt

Sceloporus variabilis marmoratus Hallowell

In Texas, as Smith (1934) has indicated, *marmoratus* tends to have more than 60 scales from the occiput to the base of the tail, while the Mexican subspecies *variabilis* has 60 or fewer than 60 scales in this computation. The differentiation is slight, but has phylogenetic significance.

One of these lizards was secured on April 5 in a pile of tin cans in a dump in a sandy, sparsely wooded area in San Patricio County.

County	Location	Date	Collector
Bandera	Medina	.....	Cutts, T. D.
Bexar	Helotes	Nov. 30, 1883	Marnock, G. W.
Duval	San Diego	.....	Taylor, W.
Live Oak	.....	Oct. 10, 1908	Mitchell, J. D.
Nueces	Nueces Bay	Dec. 17, 1891	Lloyd, W.
San Patricio	3 mi. NW. Mathis	April 5, 1931	Burt, C. E.

SOUTHWESTERN COLLEGE
WINFIELD, KANSAS

LITERATURE CITED

- BAIRD, SPENCER FULLERTON, AND GIRARD, CHARLES. 1852. Characteristics of Some New Reptiles in the Museum of the Smithsonian Institution. Part 2. Proc. Acad. Nat. Sci. Phila., pp. 125-128.
- COPE, EDWARD DRINKER. 1885. A Contribution to the Herpetology of Mexico. Proc. Am. Philosoph. Soc., 22: 379-403.
- JONES, JOHN PAUL. 1926. The Proper Name for *Sceloporus consobrinus* Baird and Girard. Occas. Pap. Mus. Zool., Univ. Michigan, No. 172: 1-3.
- ORTENBURGER, ARTHUR IRVING, AND FREEMAN, BERYL. 1930. Notes on Some Reptiles and Amphibians from Western Oklahoma. Publ. Univ. Oklahoma Biol. Surv., 2: 209-239, figs. 1-44.
- SMITH, HOBART M. 1934. On the Taxonomic Status of Three Species of Lizards of the Genus *Sceloporus* from Mexico and Southern United States. Proc. Biol. Soc. Washington, 47: 121-134.

ANYPHAENIDAE OF BARRO COLORADO ISLAND, PANAMA CANAL ZONE

ARTHUR M. CHICKERING

PETRUNKEVITCH (1933) has given adequate reasons for separating the Anyphaenidae from the remainder of the Clubionidae, and I am following his decision in this paper. Hitherto thirteen species of Anyphaenidae (Petrunkévitch, 1925; Banks, 1929) have been recorded from Panama, but only two from Barro Colorado Island: *Sillus longispinus* F. Cambridge and *Aysha similis* Banks. As indicated in the following pages of this paper, I have found twelve species in my last collection from Barro Colorado. I have the species which Banks identified as *Sillus longispinus* F. Cambridge, but after a careful examination of both and comparison with Cambridge's figures and description, I am obliged to regard my specimens as representing a new species now referred to the genus *Wulfil*. The species appearing in this paper are as follows: *Aysha insulana*, sp. nov.; *Aysha similis* Banks; *Macrophyes elongata*, sp. nov.; *Sillus coloratus*, sp. nov.; *Teudis lycosoides*, sp. nov.; *Wulfil dubia*, sp. nov.; *Wulfil fragilis*, sp. nov.; *Wulfil maculata*, sp. nov.; *Wulfil modesta*, sp. nov.; *Wulfil pellucida*, sp. nov.; *Wulfil pulverulenta*, sp. nov.; *Wulfil spinosa*, sp. nov.

In the study of species as described in this paper I have carefully examined all specimens in accordance with the intensive method used by Petrunkévitch. Because of the urgent need to conserve space and the difficulty of publication at the present time, it has been necessary to reduce the descriptions to the minimum absolutely demanded by the character of the material. This has precluded the detailed recording of spines on legs in the way practiced by Petrunkévitch and the inclusion of some other descriptive material. However, it seems probable that the leg spines and their exact distribution are somewhat less important in describing species than they have been regarded by this investigator. In making measurements the length of the body is taken from the anterior border of the carapace to the

posterior end of the abdomen. Hence the total lengths as given never include the chelicerae or the spinnerets. The cheliceral teeth on promargins and retromargins of the fang groove are counted from the inner end of each row outward toward the base of the fang. Obviously, the type locality for all new species is Barro Colorado Island. All types are to be kept in my own personal collection for the present, but it is expected that they will later be deposited in some large museum where they can receive adequate care and protection.

Petrunkévitch has recently (1930, p. 65) pointed out the great confusion now existing in the definitions of *Wulfila*, *Teudis*, *Sillus*, and *Macrophyes*. After struggling with my collection of this family I can fully appreciate his predicament. I feel confident that my *Macrophyes elongata* is a real *Macrophyes*. *Sillus coloratus* appears to be a real *Sillus*, and the same is true of *Teudis*. Of my seven specimens of *Wulfila* I am only certain that, pending a careful study of all these genera with an abundance of material, it is best to regard all as members of this genus.

KEY TO THE TWELVE KNOWN SPECIES OF ANYPHAENIDAE FROM BARRO COLORADO ISLAND

MALES

1. Tibia of palp more than twice as long as broad 2
1. Tibia of palp less than twice as long as broad 4
2. Legs and body very long and slender; palpal tibial apophysis a single short, stout spur concave at the apex *Macrophyes elongata*, p. 547
2. Legs and body shorter and stouter; palpal tibial apophysis not a single short, stout spur concave at the apex 3
3. A large species, about 11-12 mm. long; palpal tarsus deep and massive; promargin of fang groove with four stout teeth, retromargin with nine small teeth *Aysa similaris*, p. 545
3. A small species, about 4-5 mm. long; palpal tarsus not deep and massive; promargin of fang groove with four teeth, retromargin with seven teeth *Wulfila dubia*, p. 551
4. ALE with diameter more than three times as great as diameter of AME; color in alcohol yellow throughout; first ventral tibial spines 2 (irregular)-2-2 *Wulfila fragilis*, p. 553
4. ALE with diameter less than three times as great as diameter of AME; color in alcohol generally pale yellow, with broad dusty gray marginal stripes on carapace and similar dorsolateral anterior abdominal stripes; first ventral tibial spines 2-2 *Wulfila pulverulenta*, p. 558

FEMALES

1. Larger species, 9–12 mm. long; tracheal spiracle not more than one fourth the distance from genital furrow to spinnerets; diameter of AME more than one half the diameter of ALE 2
1. Smaller species, less than five mm. long; tracheal spiracle more, usually much more, than one fourth the distance from genital furrow to spinnerets; diameter of AME usually much less than one half the diameter of ALE but sometimes about equal to it 3
2. Promargin of fang groove with five teeth, retromargin with five teeth; depression in epigynum like an inverted chemical flask in shape, no notch in anterior border *Aysha insulana*, p. 544
2. Promargin of fang groove with four teeth, retromargin with nine small teeth; depression in epigynum not shaped like an inverted chemical flask; with a distinct notch in anterior border .. *Aysha similis*, p. 545
3. Eyes rather closely grouped together, PME separated by about three fourths their diameter; color brownish with a definite pattern on dorsal surface *Teudis lycosoides*, p. 549
3. Eyes more widely separated, PME separated by about their diameter or more; color yellowish with little or no pattern dorsally 4
4. Clypeus equal to a little less than radius of AME; AME separated by a little less than their radius; promargin of fang groove with three teeth, retromargin with five teeth *Sillus coloratus*, p. 548
4. Clypeus always equal to much more than the radius of AME and usually more than the diameter; AME always separated by much more than their radius and usually by at least their diameter; fang groove not with three teeth on promargin and five on the retromargin 5
5. Clypeus less than diameter of AME 6
5. Clypeus more than diameter of AME 7
6. Epigynum much longer than broad; retromargin of fang groove with four teeth *Wulfilia pellucida*, p. 557
6. Epigynum broader than long; retromargin of fang groove with seven teeth *Wulfilia dubia*, p. 551
7. Sternum and ventral side of abdomen with much gray color; promargin of fang groove with five teeth, retromargin with nine *Wulfilia maculata*, p. 555
7. Sternum and ventral side of abdomen with no gray color; promargin of fang groove not with five teeth, retromargin not with nine 8
8. Clypeus almost twice as wide as the diameter of AME; promargin of fang groove with seven teeth, retromargin with nine .. *Wulfilia modesta*, p. 556
8. Clypeus much less than twice as wide as diameter of AME; promargin with four teeth, retromargin with seven *Wulfilia spinosa*, p. 560

ANYPHAENIDAE

(Plates LVIII-LIX)

GENUS AYSHA KEYSERLING, 1891

Aysha insulana, sp. nov.

(Figures 16, 21)

Female holotype. — Total length 8.85 mm. Carapace 3.78 mm. long, sparsely covered with yellowish hair, longitudinal furrow clearly marked, widest (2.97 mm.) opposite second pair of legs.

Eyes. — All eyes circular. AME diurnal, all others nocturnal. Seen from above posterior row only slightly procurved; from in front anterior row somewhat recurved. Posterior row longer than anterior row in ratio of about 22 : 17. Ratio of eyes AME : ALE : PME : PLE = 5 : 8 : 7 : 8. AME separated from one another by about four fifths of their diameter; from ALE, by about the same distance. PME separated from one another by nine sevenths of their diameter; from PLE, by eight sevenths of their diameter. Central quadrangle wider behind than in front in ratio of 23 : 14, wider than long in ratio of 23 : 20. Clypeus wider than diameter of AME in ratio of 6 : 5.

Chelicerae. — Swollen near the base, boss prominent, basal joint 1.70 mm. long. Promargin of fang groove with five teeth, second (from inner end of row) is largest, fifth is smallest (nearest to base of fang). Retromargin of fang groove with five teeth, first is smallest, third, fourth, and fifth heavier, interval between third and fourth longest (Fig. 21). Scopula well developed only on promargin. Fang strong, evenly curved.

Lip, maxillary lobes, sternum. — Lip longer than wide in ratio of 37 : 23, slightly indented at tip. Maxillary lobes dilated in front, excavated contiguous to lip, concave along outer margin, longer than wide in ratio of 59 : 27. Sternum longer than wide in ratio of 19 : 14, sternal suture procurved, widest between second coxae, extends as a rounded projection between fourth coxae. First coxae wider apart than fourth coxae in ratio of 11 : 5.

Legs, spines, etc. — Legs, somewhat mutilated with first entirely lacking, 1(?)423. Tibial index of fourth leg 9. Spines: First leg missing. All others with ventral tibial spines 2 -- 2 -- 2; second metatarsus with ventral spines 2 (proximal), third with 2 -- 2 -- 2, fourth with 2 -- 2 -- 2. Scopulae on all tarsi, complete on second

metatarsi, at distal end of third metatarsi, vestiges at distal end of fourth metatarsi; a sparsely scopulate brush on promargin and retro-margin of second tibia. Claw tufts well developed, two claws similar with six or seven teeth.

Abdomen. — Slender and pointed behind, 4.86 mm. long, 1.93 mm. wide about one third from anterior end. Tracheal spiracle slightly more than one fourth distance from genital furrow to spinnerets, recurved and prominent. Spinnerets as usual in genus. Colulus a low, conical tubercle. Epigynum as in Figure 16, distinctive, the cavity shaped like an inverted chemical flask.

Color in alcohol. — Carapace orange, darker about the eyes; sternum yellow with brownish border, thickened opposite coxae; chelicerae, lip, and maxillary lobes deep reddish brown; legs generally yellow, with distal ends of tibiae and patellae orange; palps yellow except tarsus, the color of which is like lip, chelicerae, and maxillary lobes; abdomen yellow with darker patches and streaks dorsally.

Aysa similaris Banks

(Figures 1, 2, 12, 22)

Banks (1929) described the female of this species from Barro Colorado Island. I have specimens of both sexes and give here a description of the male allotype. The epigynum of Bank's female was not well chitinized and hence did not show the true form of this important organ. For this reason I have furnished a drawing of this organ (Fig. 12). Teeth on the female chelicera are shown in Figure 22. An additional tooth is present on the right chelicera.

Male allotype. — Total length 11.40 mm. Carapace 4.20 mm. long, 3.24 mm. wide opposite second coxae. Thoracic groove longitudinal but short and twisted in allotype. Carapace moderately high, covered with procumbent hair and a few bristles, margin with short procurved bristles.

Eyes. — Group occupies twenty-three thirty-sevenths of width of head. Seen from above posterior row slightly procurved. From in front anterior row somewhat recurved. Posterior row longer than anterior row in ratio of 11:9. AME diurnal, all others nocturnal. All eyes nearly round. Ratio of eyes AME: ALE: PME: PLE = 6:6.5:6.5:6.5. AME separated from one another by two thirds of their diameter; from ALE, by slightly more than two thirds of their diameter. PME separated from one another by nineteen thirteenths of

their diameter; from PLE, by almost the same distance. Laterals separated by slightly less than two thirds of the diameter of ALE. Central quadrangle wider behind than in front in ratio of 11:8, wider than long in ratio of 22:21. Clypeus equal to diameter of AME, with a stiff bristle beneath each space separating AME from ALE.

Chelicerae. — Prominent, porrect, diverging, excavated along distal half of inner margin, with conspicuous boss. Promargin with four teeth, retromargin with nine teeth, all essentially as in female (Fig. 22), except last two isolated. Fang long, slender, somewhat sinuous. Scopula long but scant, on promargin only.

Lip. — Longer than wide in ratio of 18:13, deeply notched at tip, basal excavations extend slightly more than one third of length.

Maxillary lobes. — Longer than wide in ratio of 29:13, dilated at tip, deeply concave along outer margin.

Sternum. — Longer than wide in ratio of 11:7, widest opposite second coxae. First coxae nearly as far apart as second, fourth coxae separated by nearly their width. Sternum ends posteriorly in a rounded point halfway between fourth coxae, somewhat convex and swollen opposite each coxa. Lengths of coxae, 14 = 23.

Legs. — 1423. Tibial index of first leg 7, of fourth leg 9. Patella of palp about two thirds as long as tibia. Spines: All tibiae with ventral spines 2--2--2; first metatarsus ventral, 2--0--0; second metatarsus like first; third and fourth metatarsi ventral 2--2--2. Claw tufts throughout well developed. Proclaw of first tarsus with sixteen teeth, retroclaw with five. Tarsal scopulae throughout, but not heavily developed, scopulae also on first and second metatarsi.

Abdomen. — Elongate, tapering. Anal tubercle prominent, with a broad base and a conical apical portion. Colulus present. Six spinnerets; anterior pair heaviest and with groove at the base on each along inner side. Posterior pair more elongate, with second segment six fifteenths as long as basal segment. Abdomen covered with short, light-colored hair. Tracheal spiracle large and only one sixth of distance from genital furrow to spinnerets. See Figures 1 and 2 for characteristics of palp, which is very broad at base. The embolus makes a complete circle and the tibial apophysis is long, slender, and somewhat hooked apically.

Color in alcohol. — Essentially as given by Banks for female, except that male allotype is probably lighter than the holotype.

GENUS MACROPHYES CAMBRIDGE, 1893

Macrophyes elongata, sp. nov.

(Figures 3, 19, 20)

Male holotype. — Total length (measured as stated in introduction) 6.05 mm. Carapace 1.99 mm. long, and 1.30 mm. wide at widest place opposite second coxae, flat, pubescent. No longitudinal groove, but a shallow pit instead.

Eyes. — The two rows of eyes nearly straight. ALE most prominent. Posterior row longer than anterior row in ratio of 14:11. Ratio of eyes AME:ALE:PME:PLE = 2:5:5:5. AME separated from one another by four thirds of their diameter; from ALE, by five thirds of their diameter. PME separated from one another by six fifths of their diameter; from PLE, by their diameter. Laterals separated by three fifths of the diameter of ALE. Central quad-angle wider behind than in front in ratio of 15:6.5, wider than long in ratio of 15:12.5. Clypeus equal to five fourths of the diameter of AME, lateral margins notched and strongly chitinated.

Chelicerae. — With basal segment 1.134 mm. long, porrect, divergent in distal half without visible boss. Fang groove difficult to follow. On left chelicera promargin with five teeth somewhat irregular, retromargin with five (Fig. 20). Right chelicera has one additional tooth on the promargin. Promargin with weak scopula, retromargin with a tuft of hairs near maxillary scopula. Fang slender and slightly sinuous.

Lip. — Longer than wide in ratio of 19:13 at the base, reaches to about the middle of maxillary lobes. The latter are slender, parallel, concave along outer border, dilate at the tips. Serrula marginal.

Sternum. — Longer than wide in ratio of 3:2, widest in the middle, ends posteriorly in blunt point between posterior coxae, which are about half as wide apart as first coxae.

Legs. — Very long and slender, 1423. Tibial index of first leg 3.5, of fourth leg 5. Tibia of palp three times longer than patella. Femur of palp strongly curved dorsoventrally. Leg spines: Ventral spines of first and second tibiae 2--2--2--2--2--2, of third tibia 2--2, of fourth tibia 1--1--1 (somewhat irregular); ventral spines of first and second metatarsi 2 (proximal), of third 2--1,

of fourth 1--1--1. Scopulae reduced on tarsi and metatarsi to remnants. Claws apparently similar with 13 or 14 teeth, difficult to determine exactly without injury to specimen. Claw tufts on all tarsi, but not strongly developed.

Palp. — Characteristics of palp shown in Figures 3 and 19. The tibial apophysis is concave at apex dorsally.

Abdomen. — Tracheal spiracle about one sixth of distance from genital furrow to spinnerets. Anterior spinnerets contiguous; posterior pair about twice as long as anterior pair, terminal segment cone-shaped, basal segment with ventral tuft of yellow hairs; median pair about two thirds as long as anterior pair. No colulus visible. Anal tubercle distinct.

Color in alcohol. — Generally yellow. Legs almost white, carapace lemon-yellow, mouth parts somewhat darker, sternum almost white, abdomen dusty yellow.

The genus *Macrophyes* was established by O. P. Cambridge for a single adult male from Mexico. No members of this genus are in the collection from Central America in the Museum of Comparative Zoölogy, Harvard University. It seems to be a rare genus, and this is the first record from Central America so far as I am aware. Knowledge concerning females is much needed.

GENUS SILLUS F. CAMBRIDGE, 1896

Sillus coloratus, sp. nov.

(Figures 10, 23, 32)

Female holotype. — Total length 3.24 mm. Carapace 1.22 mm. long, 0.96 mm. wide opposite second coxae, at level of posterior eyes 0.64 mm. wide, truncate posteriorly, with longitudinal thoracic groove, covered sparsely with dark procumbent hair. Abdomen 1.87 mm. long (cephalothorax and abdomen slightly separated).

Eyes. — Seen from above posterior row of eyes nearly straight, anterior row recurved, laterals not elevated. Ratio of eyes AME: ALE: PME: PLE = 2.5:3.5:3:3 (Fig. 23). AME separated from one another by a little more than their radius; from ALE, by about their radius. PME separated from one another by about four thirds of their diameter; from PLE, by their diameter. Laterals separated by a little less than the radius of PLE. PLE somewhat oval, PME quite oval in outline. Central quadrangle wider behind than in

front in ratio of 20 : 13, wider than long in ratio of 10 : 7. Clypeus a little less than the radius of AME.

Chelicerae. — Parallel, basal segment 5.35 mm. long, with boss well developed. Promargin with three stout teeth, retromargin with five much smaller teeth (Fig. 32). Fang fairly stout, curved as usual. Scanty scopula on promargin only.

Lip. — Longer than wide in ratio of 9 : 8, reaches just beyond middle of maxillae, anterior border slightly indented.

Maxillary lobes. — Parallel, concave along outer margin, dilated at tips, longer than wide in ratio of 17 : 8, with serrula extending along entire anterior border, and with palp inserted one third of distance from proximal end.

Sternum. — Longer than wide in ratio of 29 : 21, widest opposite interval between first and second coxae, sternal suture slightly recurved, ends bluntly halfway between posterior coxae, somewhat convex, first coxae more than twice as far apart as posterior coxae.

Legs. — 4123, generally short and stout. Tibial index of first and fourth legs 13. Ventral spines of first tibia 2 -- 2 -- 0; of first metatarsus 2 -- 1p -- 0; of second tibia 2 -- 1r; of second metatarsus 2 -- 1p -- 0; of third tibia 0; of third metatarsus 2 -- 2 (apical); of fourth tibia 0 -- 1p -- 0 (a pair of bristles); of fourth metatarsus 2 -- 2 (apical). Third and fourth metatarsi have promarginal and retromarginal spines which may represent the preening comb.

Abdomen. — Ovoid. Tracheal spiracle nearly halfway from genital furrow to spinnerets. Spinnerets typical for the genus. Characteristics of epigynum in Figure 10.

Color in alcohol. — Abdomen nearly white throughout; carapace and sternum light yellow, with brown about the eyes; lip and maxillary lobes light brown, chelicerae deep rich brown; legs yellowish white.

GENUS TEUDIS CAMBRIDGE, 1896

Teudis lycosoides, sp. nov.

(Figures 13, 26, 26 A)

Female holotype. — Total length 4.53 mm., carapace 2.12 mm. long, abdomen 2.38 mm. long (the two portions of the body overlap slightly). Carapace widest opposite second coxae, where it is 1.51 mm., narrowed in front to 1.06 just in front of first coxae. Longitudinal thoracic groove clear and sinuous.

Eyes. — Posterior row of eyes gently procurved, anterior row somewhat recurved. Posterior row longer than anterior row in ratio of 22 : 15. A single stiff bristle between AME. Ratio of eyes AME : ALE : PME : PLE = 2 : 5.5 : 5 : 5. AME separated from one another by almost their radius, nearly in contact with ALE. PME separated from one another by three fifths of their diameter; from PLE, by their radius. Laterals separated by about one third of diameter of ALE (Fig. 26). Central quadrangle wider behind than in front in ratio of 12 : 5, longer than wide in ratio of 7 : 6. Clypeus equal to about three halves of diameter of AME.

Chelicerae. — Outer margins of chelicerae parallel, inner distal corner truncate, basal segment about half as long as cephalothorax. Boss prominent. Retromargin with five small teeth (differences noticeable on two sides). Promargin with four teeth, second largest (Fig. 26 A). Scopula of medium prominence along promargin. Fang fairly stout.

Maxillary lobes. — Parallel, gradually widening from base toward apex, where they are only slightly dilated. Palp inserted near base. Lip longer than wide in ratio of 8 : 7, extends about two thirds of length of the maxillary lobes.

Sternum. — Longer than wide in ratio of 44 : 35, extends halfway between posterior coxae, where it ends in a point bearing a tuft of three or four bristles. Anterior coxae wider apart than posterior coxae in ratio of 30 : 7.

Legs. — 4123. Tibial index of first leg 12, tibial index of second leg 14. Ventral spines of first tibia 2 - 2 (a pair of apical bristles may represent the pair of spines supposed to be characteristic of the genus), of second tibia 1r - 1r, of third tibia 2 - 1p - 1r, of fourth tibia 2 - 2 - 2. Ventral spines of first metatarsus 2 - 0 - 0, of second metatarsus the same, of third metatarsus 2 - 2 - 1, of fourth metatarsus 2 - 2 - 0. Claw tufts and tarsal scopulae lightly developed throughout, scopulae extend as weakly developed brushes the length of the first two metatarsi, but are restricted to region of the preening comb on metatarsi three and four. Claws apparently similar, each with about five teeth.

Abdomen. — Tracheal spiracle slightly closer to spinnerets than to genital furrow. Abdomen elongate, ovoid. Anal tubercle a fairly prominent cone. Anterior spinnerets yellowish, contiguous, a little longer than posterior spinnerets, which are brown. Character-

istics of the epigynum shown in Figure 13. This organ is distorted, and it is impossible to determine which half is the normal one.

Color in alcohol. — Generally brownish. Carapace well marked, with a central light strip from posterior eyes to posterior border nearly as wide as the posterior row of eyes in front, but somewhat narrowed behind the middle. A light stripe on each side of carapace just above margin extending forward to region between first and second coxae. The remainder is colored much darker, thus making two narrow submarginal dark stripes together with the two lateral dark stripes and the three light stripes referred to above. The whole pattern on the carapace recalls the markings of many Lycosidae, from which fact the specific name is derived. The darker stripes are much flecked and streaked with more deeply colored areas. Sternum is brownish and much flecked with darker patches. Legs are much spotted and ringed with dark areas. Abdomen is spotted with dark brown and yellow areas above, lighter beneath; centrally above there is a row of irregular spots increasing in size from anterior to posterior end.

GENUS WULFILA CAMBRIDGE, 1895

Wulfila dubia, sp. nov.

(Figures 4, 15, 29)

Male holotype. — Total length 4.32 mm. Carapace 1.89 mm. long, 1.46 mm. wide between second coxae, finely pubescent, rather flat, of nearly the same height until just behind the prominent longitudinal thoracic furrow, from which it is steeply declivitous to the posterior margin.

Eyes. — In two rows. Posterior row longer than anterior row in ratio of 27:22. ALE somewhat raised and projecting. Seen from above posterior row slightly recurved, anterior row much recurved. Ratio of eyes AME: ALE: PME: PLE = 2.5:6:5.5:5. AME separated from one another by their diameter; from ALE, by a little greater distance. PME separated by a little less than their diameter; from PLE, by about the same distance. Laterals separated by one third of diameter of PLE. Quadrangle wider behind than in front in ratio of 2:1, wider than long in ratio of 7:6. Clypeus equal to six fifths of diameter of AME.

Chelicerae. — With basal segment 1.066 mm. long, divergent,

somewhat porrect, distal half of basal segment excavated along inner dorsal margin as in *Wulfilia tropica* Petrunkevitch, with boss. Promargin with four teeth, first the smallest, second the largest; retromargin with seven teeth having irregular distribution (Fig. 29). Scanty scopula along promargin only. A small tuft of hairs on retromargin obscured by maxillary scopula. A low tubercle nearly in middle on retrolateral surface. Fang long and somewhat sinuous.

Lip. — Longer than wide in ratio of 17 : 12, sides nearly parallel, somewhat rounded distally, reaches just beyond the middle of maxillary lobes, anterior end nearly straight, with a few stiff convergent bristles.

Maxillary lobes. — Almost twice as long as wide, concave along outer edge, palp inserted in proximal third, serrula long and extended laterally over the outer angles.

Sternum. — Shield-shaped, almost equally wide between first and second coxae, sternal suture somewhat procurved, ends bluntly between posterior coxae, which are separated by nearly their width, longer than wide in ratio of 40 : 33, with three pairs of sigilla, moderately convex.

Legs. — Long and slender, 1423. Tibial index of first leg 7, of fourth leg 8. Tibia of palp a little more than one and one third as long as the patella. Ventral tibial spines of first leg 2 - 2 (one lacking on left tibia), of second leg same as in first, of third leg 1 - 1 - 2 (apical), of fourth leg 2 - 2 - 2. Ventral metatarsal spines of first leg 2 - 2, of second leg the same, of third leg 2 - 2 - 2 and a preening comb, of fourth leg the same. Nothing but vestiges of tarsal and metatarsal scopulae. Claw tufts throughout of two rows, each of about seven tenent hairs. Proclaw with five teeth, retroclaw with four.

Palp. — Shown in Figure 4. Tibia with an apophysis which is short, broad, and with two points.

Abdomen. — Long, ovoid. Postabdomen is prominent. Abdomen covered with sparse stiff bristles more or less erect and recumbent hair (both badly rubbed off in type). Tracheal spiracle a little closer to genital furrow than to spinnerets. Anterior pair of six spinnerets stout and closely apposed, middle pair slenderer, but nearly as long as anterior pair, posterior pair slenderer and one third longer than anterior pair.

Color in alcohol. — Abdomen nearly white, with faint indications

of two dorsal dusty stripes; legs, cephalothorax, and palps deeper yellow. Mouth parts brownish.

Female allotype. — Total length 3.89 mm. Carapace 1.62 mm. long, 1.19 mm. wide between second coxae, with longitudinal thoracic groove, dark, procumbent hair sparsely distributed.

Eyes. — Posterior row of eyes almost straight, anterior row recurved. Eye group narrower than width of head in ratio of 25:32. Posterior row of eyes wider than anterior row in ratio of 25:19. ALE somewhat raised. Ratio of eyes AME:ALE:PME:PLE = 2.5:4.5:4:4. AME separated from one another by three fifths of their diameter; from ALE, by about four fifths of their diameter. PME separated from one another by their diameter; from PLE, by their diameter. Laterals separated by the radius of PLE. Clypeus about four fifths of the diameter of AME. Quadrangle wider behind than in front in ratio of almost 2:1, wider than long in ratio of 13:11.

Chelicerae. — Parallel, with boss, promargin with five teeth, of which the last is very minute, retromargin with seven teeth, first four closer, last three more openly arranged. A rather scanty scopula on promargin, with a few isolated hairs on retromargin near inner end. Fang evenly curved and of normal size.

Maxillae, lip, and sternum. — Essentially as in male holotype.

Legs. — 1 = 423. Tibial index of first leg 8, of fourth leg 10. Ventral tibial and metatarsal spines as in male. Other features as in male, including color.

Epigynum. — Features shown in Figure 15. Rather coarse yellow hair covers the epigynum, and this is cleaned away for drawing.

Four female and three male paratypes. One female has four distinct dusky stripes on abdomen.

***Wulfilia fragilis*, sp. nov.**

(Figures 7, 8, 31)

Male holotype. — Total length 3.13 mm. Carapace 1.40 mm. long, 1.19 mm. wide between first and second coxae, gradually narrowed posteriorly, sharply narrowed anteriorly, where it is 0.64 mm. wide at level of posterior eyes, with longitudinal thoracic groove faintly visible, quite convex, gently arched to near the posterior border.

Eyes. — Seen from above both rows of eyes nearly straight. Lateral eyes scarcely elevated. Ratio of eyes AME:ALE:PME:PLE = 1.5:4.75:4:4.75. AME separated from one another by four thirds of their diameter; from ALE, by slightly more than their diameter. PME separated from one another by five fourths of their diameter; from PLE, by slightly less than their diameter. Laterals separated by the radius of PME. Quadrangle wider behind than in front in ratio of 12:5, wider than long in ratio of 6:5. Clypeus below AME equal to twice the diameter of AME.

Chelicerae. — Without visible boss, parallel, 0.533 mm. long (basal segment). Promargin with five teeth quite variable in size, second largest, third and fifth very small; retromargin with a row of very small teeth, probably eight, last one very minute and isolated (Fig. 31). Fang of usual proportions, evenly curved. Scopula on promargin only, scanty. Small group of hairs on retrolateral surface midway, covered by maxillary lobes. Maxillary lobes parallel, longer than wide in ratio of 18:11, not very concave along outer border nor much dilated apically, palp inserted in basal third, serrula long, submarginal.

Lip. — Longer than wide in ratio of 11:8, reaches a little beyond middle of the maxillary lobes, somewhat indented at apex.

Sternum. — Longer than wide in ratio of 17:15, widest between second coxae. Anterior coxae wide apart, posterior coxae separated by a little more than their width. Sternum ends in a blunt point, which extends completely between posterior coxae.

Legs. — 1423. Tibial index of first leg 6, of fourth leg 8. First legs very long and slender. Tibial ventral spines of first leg 2 (irregular) -- 2 -- 2, of second leg 2 -- 2 -- 0, of third leg 2 -- 2 -- 0, of fourth leg 1p -- 1p -- 0. Ventral metatarsal spines of first leg 2 -- 2, of second leg the same, of third leg the same, of fourth leg 2 -- 2 -- preening comb. Claw tufts throughout, each of a very few tenent hairs. Apparently scopulae are lacking in this species. Characteristics of the palp are shown in Figures 7 and 8. The tibia is very broad and only a little longer than the patella.

Abdomen. — Ovoid as usual in these *Wulfilae* from Panama. Spinnerets as usual. Tracheal spiracle about two fifths of distance from genital furrow to spinnerets.

Color in alcohol. — Pale yellow throughout, with a few very faint dusky spots on abdomen.

Wulfila maculata, sp. nov.

(Figures 9, 18, 24)

Female holotype. — Total length 4.0 mm. Carapace 1.42 mm. long, widest opposite second coxae, where it is 1.08 mm. Longitudinal thoracic groove present. Carapace rather low and flat, cephalic portion glabrous, thoracic portion covered with sparse yellow hair.

Eyes. — Seen from above posterior row of eyes straight, anterior row recurved. Posterior row longer than anterior row in ratio of 11:8. Posterior row of eyes shorter than width of head at same level in ratio of 11:13. Ratio of eyes AME:ALE:PME:PLE = 3.5:9:8:8. AME separated from one another by a little less than their diameter; from ALE, by a little more than their diameter. PME separated from one another by five fourths of their diameter; from PLE, by three fourths of their diameter. Laterals separated by a little less than diameter of ALE. Quadrangle wider than long in ratio of 12:11, wider behind than in front in ratio of 12:5. Clypeus just a little more than three halves of diameter of AME.

Chelicerae. — With well-developed boss, nearly parallel, with basal segment 0.64 mm. long or about two fifths of length of carapace. Promargin with five stout teeth, retromargin with nine very small teeth the first four being crowded, the last five more widely spaced and somewhat larger (Fig. 24). Scopula weakly developed on promargin only.

Lip. — Longer than wide in ratio of about 5:3, basal excavations reach about two fifths of the length of the organ, extends a little beyond the middle of maxillary lobes.

Maxillary lobes. — Parallel, slightly convex along lateral border, slightly dilated apically, longer than wide in ratio of 2:1, palp inserted near the base. Sternal suture very strongly procurved.

Sternum. — Longer than wide in ratio of 9:7, widest opposite first and second coxae. First coxae very wide apart, fourth coxae separated by about their width.

Legs. — 1423. Tibial index of first leg 4, of fourth leg 7. Ventral spines of first tibia 2-2---2---0; of second tibia 2-2---0; of third tibia 1r--1p--0; of fourth tibia 1r--1r. Ventral spines of first metatarsus 2-2-1r, last one just distal to the middle; second metatarsus 2--1r--2 (last pair near the middle); third metatarsus 2--2 (irregular); fourth metatarsus 2--2 (irregular).

Spines of this specimen are difficult to determine with certainty. Spines of a paratype female are different from those of type, and this casts doubt on the importance of these spines as a thoroughly reliable specific character. Claw tufts reduced to a few tenent hairs. Claws two. Scopulae on tarsi very much reduced.

Abdomen. — Elongate-ovoid, with tracheal spiracle a little closer to genital furrow than to spinnerets. Characteristics of the epigynum shown in Figure 18.

Color in alcohol. — Abdomen, shown in Figure 9, is almost white dorsally, but ventrally it is marked with gray. Carapace yellowish white. Sternum with a broad strip of gray covering all but narrow lateral margins, which are yellowish. Lip, maxillary lobes, and chelicerae all yellowish. Legs nearly all white or yellowish, except at the first tibio-metatarsal and metatarso-tarsal joints, where spots of black give a very characteristic appearance.

One female paratype in addition to the female holotype.

***Wulfil modesta*, sp. nov.**

(Figures 14, 25)

Female holotype. — Total length 4.21 mm. Carapace 1.73 mm. long, widest between first and second coxae, where it measures 1.3 mm., 0.76 mm. wide at level of posterior eyes, gently increases in height from posterior eyes to just behind the faintly visible longitudinal thoracic furrow, where it becomes declivitous to the posterior truncated margin. Abdomen 2.48 mm. long.

Eyes. — Seen from above the posterior eyes almost straight, anterior eyes gently recurved. Posterior row longer than anterior row in ratio of 4:3. Laterals slightly elevated. Ratio of eyes AME:ALE:PME:PLE = 1.75:4:3.75:3.75. AME separated from one another by their diameter; from ALE, by the same distance. PME separated from one another by fifteen sixteenths of their diameter; from PLE, by their diameter. Laterals separated by diameter of AME. Central quadrangle wider behind than in front in ratio of 2:1, wider than long in ratio of 10:9. Clypeus wider than the diameter of AME in ratio of 8:7.

Chelicerae. — Parallel, with prominent boss, basal segment 0.64 mm. long. Promargin with a row of seven teeth second largest, last very minute (Fig. 25). Retromargin with a row of nine very minute teeth the first five closely crowded, the last four more openly

arranged. Scopula weakly developed along promargin only. Fang as usual in this genus from Barro Colorado.

Lip. — Longer than wide in ratio of 13:9, reaches beyond the middle of the maxillary lobes.

Maxillary lobes. — Parallel, longer than wide in ratio of about 2:1, only slightly concave along middle of outer margin, only a little dilated apically, with palp inserted on the basal third. Serrula along whole distal lateral border.

Sternum. — Longer than wide in ratio of 4:3, widest between second coxae, nearly as wide between first coxae. Sternal suture only gently procurved. Fourth coxae separated by their width. Sternum ends bluntly between fourth coxae.

Legs. — Legs are probably 1423, as in other closely related species, but in the type the first three pairs are lacking. The paratype female (injured) indicates the leg formula as given above. Tibial index of fourth leg 10. Female paratype shows ventral tibial spines of first leg 2-2-0, of second leg the same, of third leg 1--2, of fourth leg 1p--2. Female paratype shows ventral metatarsal spines of first leg 2-2-0, of second leg the same, of third leg 2-2--preening comb, of fourth leg same as third. Claw tufts throughout. Tarsal scopulae weakly developed.

Abdomen. — Ovoid, with tracheal spiracle midway between genital furrow and spinnerets. Spinnerets as usual in this genus. Characteristics of epigynum shown in Figure 14.

Color in alcohol. — Pale yellow throughout.

One female paratype in addition to the holotype.

***Wulfila pellucida*, sp. nov.**

(Figure 11)

Female holotype. — Total length 2.59 mm. Carapace 1.08 mm. long, widest between second coxae, where it is 0.81 mm. in width, truncated at posterior end, narrowed in front, where it is 0.432 mm. wide at level of posterior row of eyes. No longitudinal thoracic furrow visible, apparently a shallow pit instead. Abdomen 1.51 mm. in length.

Eyes. — Seen from above posterior row of eyes slightly procurved, anterior row gently recurved. Laterals somewhat elevated. Ratio of eyes AME:ALE:PME:PLE = 1.5:3.5:3:3. AME separated from one another by two thirds of their diameter; from ALE, by about

the same distance. PME separated from one another by their diameter; from PLE, by a little less than their diameter. Laterals separated by about one third of diameter of PLE. Quadrangle wider behind than in front in ratio of 9:4, only very slightly wider than long. Clypeus equal to about three fourths of diameter of AME.

Chelicerae. — Parallel, without evident boss, scanty scopula on promargin only. Fang groove very difficult to see without serious injury to the specimen. Promargin (?); retromargin with four fairly stout teeth, last one the smallest. Fang as usual in this genus.

Lip. — Almost as wide as long, basal excavations reach about one third length of lip, which extends just beyond middle of maxillary lobes.

Maxillary lobes. — Parallel, longer than wide in ratio of 13:9, palp inserted near the middle, only slightly concave along outer margin and only slightly dilated apically. Serrula along nearly the entire anterior border. Scopula weak and only on promargin.

Sternum. — Longer than wide in ratio of 5:4, widest between second coxae, almost as wide between first coxae, fourth coxae two thirds as wide apart as second. Sternum ends very bluntly between fourth coxae.

Legs. — 1(?)423, first leg missing. Tibial index of fourth leg 11. Ventral tibial spines of second leg, a single spine near the middle, of third leg 0, of fourth leg 0. Ventral metatarsal spines of second leg 2-2-0, of third leg 1p--0--preening comb, of fourth leg 1r--0--1p--preening comb. Claw tufts throughout. Only vestiges of tarsal scopulae present.

Abdomen. — Ovoid, tracheal spiracle three sevenths of distance from genital furrow to spinnerets, spinnerets as usual in this genus. Characteristics of epigynum shown in Figure 11.

Color in alcohol. — Almost entirely unicolorous yellow, with slight variations in different parts of the body.

***Wulfila pulverulenta*, sp. nov.**

(Figures 5, 6, 30)

Male holotype. — Total length 2.92 mm. Carapace 1.30 mm. long, moderately convex and of nearly same height from posterior eyes to near the posterior end, where it slopes off precipitously, widest opposite second coxae, where it is 1.17 mm. wide, narrowed in the cephalic region, where it is 0.556 mm. wide at level of posterior

row of eyes (thus much more nearly circular than in most species), longitudinal thoracic groove present but very inconspicuous, glabrous except at margins. Abdomen 1.62 mm. long.

Eyes. — Seen from above, posterior row straight, anterior row somewhat recurved. Posterior row longer than anterior row in ratio of 21:16. Laterals slightly elevated. Ratio of eyes AME: ALE: PME: PLE = 1.75:4.5:4.5:4.5. AME separated from one another by a little less than their diameter; from ALE, by about the same distance. PME separated from one another by their diameter; from PLE, by almost their diameter. Laterals separated by almost the diameter of AME. Quadrangle wider behind than in front in ratio of 12:5, wider than long in ratio of 12:11. Clypeus nearly perpendicular and equal to about three halves the diameter of AME.

Chelicerae. — Nearly parallel, slightly concave on outer margin near the middle, with slightly developed boss, promargin with a row of five stout teeth, with the last two somewhat larger, retro-margin with eight very small teeth (Fig. 30). Scopula as usual and on promargin only.

Lip. — Longer than wide in ratio of 11:8, basal excavations reach to the middle.

Maxillary lobes. — Parallel, only slightly concave in middle of outer margin and only slightly dilated apically, longer than wide in ratio of 16:11.

Sternum. — Broad in front, narrowed to a blunt point between posterior coxae. Widest between first coxae, 0.668 mm.

Legs. — 1423. Tibial index of first leg 6, of fourth leg 8. Tibial ventral spines of first leg 2-2, of second leg the same. Metatarsal ventral spines of first leg 2-2-0, second metatarsus the same. Preening comb apparently on third and fourth metatarsi. Two claws and claw tufts throughout. Tarsal scopulae lacking or reduced. See Figures 5 and 6 for characteristics of palp.

Abdomen. — Ovoid, tracheal spiracle about midway of distance from genital furrow to spinnerets, which are normal.

Color in alcohol. — Generally pale yellow throughout, with variations in intensity of color. Carapace with broad dusty gray marginal stripes, abdomen with two dorsolateral stripes of the same gray on anterior half and two dim gray spots dorsally near the middle.

One mature and one immature male paratype, as well as the type.

Wulfila spinosa, sp. nov.

(Figures 17, 27, 28)

Female holotype. — Total length 5.29 mm. Carapace 2.27 mm. long; thoracic groove longitudinal, long and distinct. Carapace widest opposite second coxae, narrowed anteriorly but not strongly so, covered with procumbent yellow hair. Row of three bristles on each side just posterior to PLE obliquely placed. One long and one short bristle between AME. Also row of bristles along clypeus, some broken, but probably at least six in row.

Eyes. — Seen from above posterior row of eyes slightly procurved, anterior row slightly recurved. Posterior row longer than anterior row in ratio of 31:24. AME alone diurnal. Ratio of eyes AME:ALE:PME:PLE = 2.5:6:5:5.5. AME separated from one another by a little more than their diameter; from ALE, by almost their diameter. PME separated from one another by six fifths of their diameter; from PLE, by the same distance. Laterals separated by the diameter of AME. Quadrangle wider behind than in front in ratio of 2:1, wider than long in ratio of 8:7. Clypeus equal to eight fifths of the diameter of AME (Fig. 28).

Chelicerae. — Of normal size, with well-developed boss and a normal fang; promargin with four teeth, retromargin with seven teeth, first and last very small (Fig. 27). Scopula only on promargin, fairly well developed.

Lip. — Longer than wide in ratio of about 2:1, anterior border with a row of stiff bristles converging toward middle, reaches just beyond middle of maxillary lobes.

Maxillary lobes. — Nearly parallel, only a little concave laterally and only mildly dilated apically, serrula long and marginal, palp inserted near the base.

Sternum. — Longer than wide in ratio of 6:5, ends bluntly between posterior coxae.

Legs. — 4123. Tibial index of first leg 8; tibial index of fourth leg 9. First ventral tibial spines 2--2; first ventral metatarsal spines 2--0--0; second ventral tibial spines 2--2; second ventral metatarsal spines 2--0--0; third ventral tibial spines 2--1--2; third ventral metatarsal spines 2--2--2; fourth tibia and metatarsus so injured as to be unfit for study of spines. Claws two. Claw tufts throughout. First and second tarsi and

metatarsi scopulate throughout; scopulae extend weakly along first and second tibiae in two bands; scopulae very much reduced on third and fourth tarsi and represented on these metatarsi only by apical tufts.

Abdomen. — 3.0 mm. long, ovate, with scattered black bristles dorsally. Anal tubercle prominent. Tracheal spiracle about three sevenths of distance from genital furrow to spinnerets. Epigynum as in Figure 17.

Color in alcohol. — Yellow throughout; legs somewhat darker, especially at ends of segments.

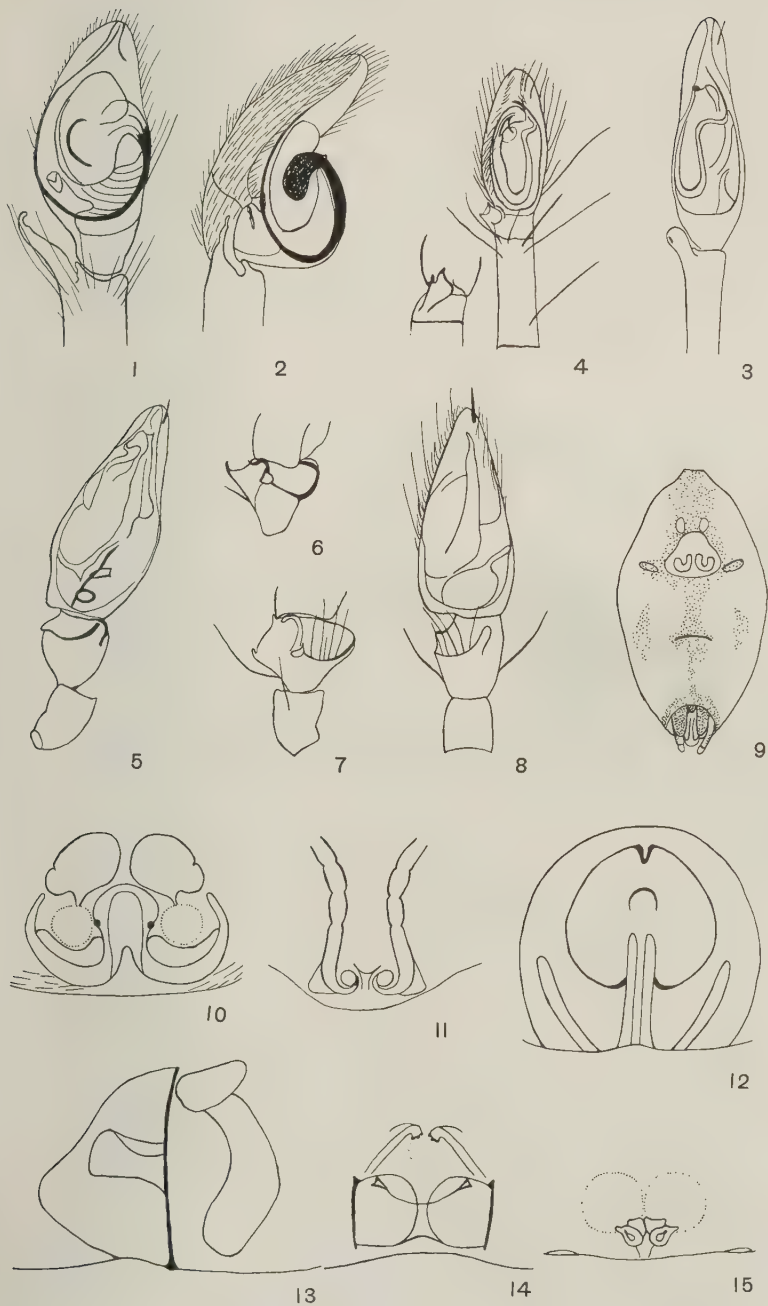
ALBION COLLEGE
ALBION, MICHIGAN

LITERATURE CITED

- BANKS, NATHAN. 1929. Spiders from Panama. Bulletin of the Museum of Comparative Zoölogy, 69: 53-96, 4 pls.
- CAMBRIDGE, O. P., AND CAMBRIDGE, F. P. 1889-1905. Arachnida-Araneida, Vols. I-II. In *Biologia Centrali Americana*, Dulau & Co., London.
- CHAMBERLIN, RALPH V. 1925. Diagnoses of New American Arachnida. Bulletin of the Museum of Comparative Zoölogy, 67: 211-248.
- PETRUNKEVITCH, A. 1925. Arachnida from Panama. Transactions of the Connecticut Academy of Arts and Sciences, 27: 51-248.
- 1930. The Spiders of Porto Rico. Part III. *Ibid.*, 31: 1-191.
- 1933. An Inquiry into the Natural Classification of Spiders, Based on a Study of Their Internal Anatomy. *Ibid.*, 31: 299-389.

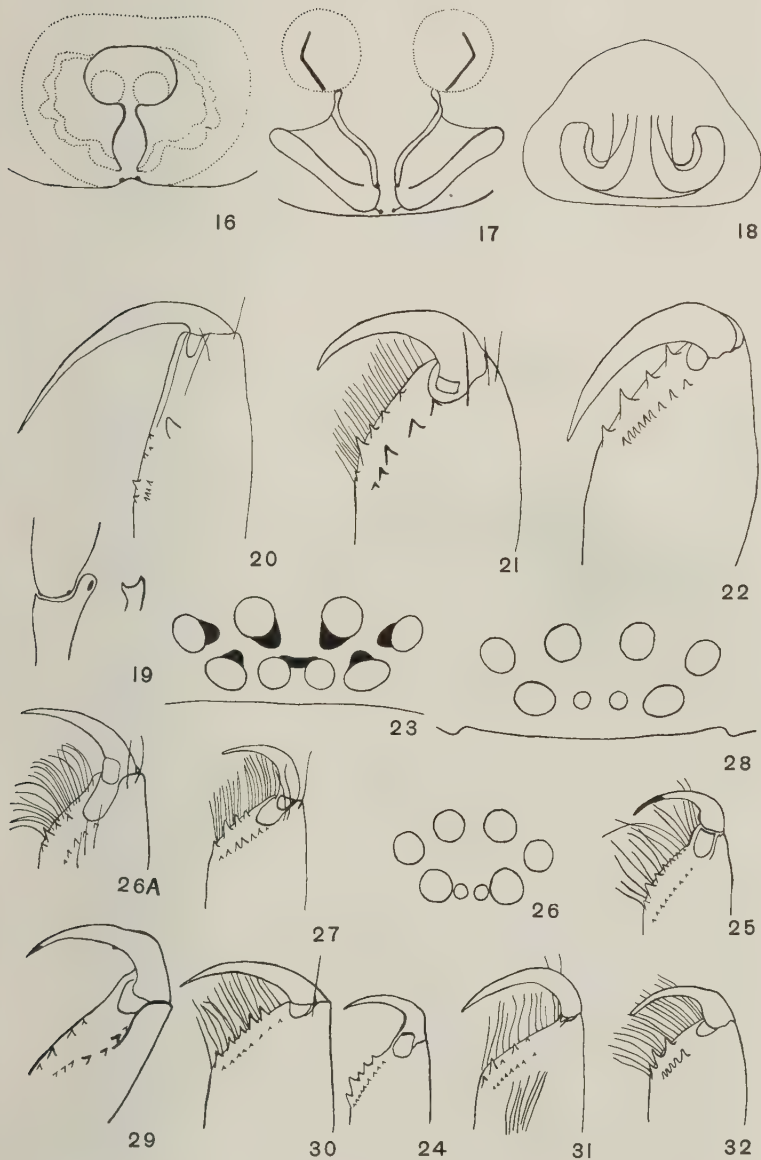
PLATES LVIII-LIX

PLATE LVIII



External anatomy of the spider

PLATE LIX



External anatomy of the spider

AGE, GROWTH, AND MORPHOMETRY OF THE
CISCO, *LEUCICHTHYS ARTEDI* (LE SUEUR),
IN BLIND LAKE, WASHTENAW
COUNTY, MICHIGAN *

GERALD P. COOPER

BLIND LAKE, which is situated in the southeast corner of Section 1 of Lyndon Township, Washtenaw County, Michigan, is one of a series of lakes that form the headwaters of the Huron River. This is a typical marl lake of approximately 50 acres surface area, with a reported maximum depth of about 60 feet. The marginal area of water, 5 feet deep or less, varies from 10 to 100 feet in width. At the west end of the lake there is a well-defined cove approximately 5 acres in area, with a maximum depth of 25 feet. The most important of the food fishes of Blind Lake are the northern pike (*Esox lucius*), the bluegill (*Helioperca macrochira*), the large-mouthed black bass (*Aplites salmoides*), and the cisco (*Leucichthys artedi*). From the latter part of November through December night spearing of the cisco on the spawning grounds is a popular sport among the local fishermen. A considerable portion of the cisco population spawns in the bay at the west end of the lake.

The 152 ciscoes considered in this paper were collected¹ from their spawning grounds in the west bay on December 1 and 2, 1934. Of this number, 125 specimens were taken in a 280-foot experimental gill net composed of two 20-foot pieces of netting of each of the following stretched meshes: $1\frac{1}{4}$, $1\frac{1}{2}$, $2\frac{1}{4}$, $2\frac{1}{2}$, $2\frac{7}{8}$, $3\frac{1}{2}$, and 4 inches. This net was fished continuously from 6 P.M. on December 1 to 8 P.M. on December 2. The remaining 27 specimens were taken by spear (from 8 P.M. on December 1 to 3 A.M. on December 2 and from 6 P.M.

* A contribution from the Institute for Fisheries Research, the Department of Conservation, State of Michigan, and the University of Michigan. The writer wishes to thank Dr. John Van Oosten and Dr. Ralph Hile for their valuable criticism of the manuscript.

¹ The collecting party included R. W. Eschmeyer, Neil W. Hosley, Glen R. Brooks, and the writer.

to 8 P.M. on December 2). This collection is presumably a random sample of fish that were on the spawning grounds during this period.

Of the 152 specimens collected, 130 were examined immediately after they were taken from the lake. The standard and the total lengths were measured (to the nearest one eighth of an inch), the sex and the stage of maturity were determined, and scale samples were taken from each fish. The remaining 22 specimens were preserved in 10 per cent formalin, and after four days were transferred to 70 per cent alcohol. The lengths were measured (to the nearest millimeter), the sex and the stage of maturity were determined, and scale samples were taken from these 22 specimens approximately two months after preservation. For use in age and growth studies their lengths were corrected to allow for the shrinking effect of the preserving fluids by employing the corrective factor 1.016 given by Van Oosten (1929).

MORPHOMETRY

Although a considerable amount of work has been done on the systematics of the Coregonidae, the status of the different forms in this very plastic group is a perplexing and unsettled problem. The species *Leucichthys artedi* is particularly confusing. Koelz (1931) recognized twenty-four subspecies of *artedi* occurring in northeastern America. However, Hile (1936), by an intensive study of cisco populations in Wisconsin lakes, has been able to demonstrate that the range of the various morphometric characters utilized by Koelz in distinguishing certain forms is very large in relation to recorded differences and, further, that these characters are subject to considerable fluctuation, varying with the rate of growth of the individual fish. Hile concluded that "the current elaborate systematization of the species set forth by Koelz (1931) is in large measure invalid." It is a certainty that many more data will be necessary before the coregonid taxonomist can arrive at a reliable systematic arrangement of the many coregonid forms. For this reason the writer believes it desirable to include morphometric data from the 22 specimens which were preserved and studied in the laboratory. These data are given in Table I. The measurements and the counts on which they are based were made in the manner described by Koelz (1929). The proportions were calculated from measurements taken to the nearest millimeter.

TABLE I

MORPHOMETRIC DATA FROM 22 SPECIMENS OF *LEUCICHTHYS ARTEDI*
FROM BLIND LAKE

L = standard length; H = length of head; D = depth of body;
S = length of snout; M = length of maxillary; E = diameter
of eyeball; PV = distance between insertions of pectoral and
ventral fins; and P = length of pectoral fin

Sex and ma- turity	Age groups	Stand- ard length in mm.	Gill rakers	Lateral line scales	L/H	L/D	H/S	H/M	H/E	PV/P
♀ im.	0	130	45	90	4.5	5.0	4.1	3.2	3.6	2.0
"	I	163	46	83	4.6	4.5	4.5	3.0	4.0	1.9
♀ ad.	I	179	47	94	4.5	4.3	4.0	3.1	3.6	2.0
"	II	183	48	85	4.1	4.2	4.1	2.8	3.8	2.1
"	III	189	45	90	4.2	4.2	4.5	3.0	3.8	2.1
"	III	189	45	85	4.3	4.5	4.4	2.9	3.7	1.9
"	III	196	49	89	4.3	4.2	4.2	2.9	3.8	1.9
"	II	202	47	88	4.4	4.2	4.2	3.1	4.2	2.4
♂ ad.	II	177	47	88	4.2	4.0	4.2	3.0	3.8	1.7
"	I	176	47	83	4.3	4.1	3.9	2.9	3.9	2.0
"	II	185	45	86	4.2	4.5	4.0	2.9	3.4	1.7
"	III	189	47	89	4.2	4.2	4.5	3.0	4.1	2.1
"	III	192	47	85	4.0	4.2	4.0	3.0	4.0	1.7
"	II	197	48	86	4.5	4.5	4.4	2.9	4.0	2.1
"	II	197	45	83	4.3	4.6	4.2	2.9	4.2	2.0
"	II	199	45	87	4.2	4.4	4.3	2.9	3.9	1.9
"	IV	219	49	88	4.3	4.3	3.9	2.7	3.9	1.9
"	V	219	46	83	4.3	4.2	4.3	2.8	3.9	1.9
"	IV	223	42	84	4.1	3.8	4.2	3.1	4.2	1.6
"	IV	224	46	82	4.3	4.4	4.0	2.7	4.0	1.9
"	II	229	45	86	4.3	4.0	4.3	3.1	4.3	1.9
"	VI	246	49	85	4.2	4.5	4.1	3.1	4.1	1.9
Mean		196	46.4	86.3	4.29	4.31	4.20	2.95	3.92	1.94

Koelz (1931) recorded a single specimen of *Leucichthys artedi* from Blind Lake and stated that "The values found for the various systematic characters of this fish fall within the range of those for typical *artedi*." The averages of morphometric counts and measurements on Blind Lake ciscoes given in Table I fall within the range of corresponding data given by Koelz for the subspecies *artedi*. However, for these Blind Lake ciscoes the average value for the number of gill rakers is lower, and the average values for the number of lateral line scales and H/S are much higher than for the

various populations of the subspecies *artedi* recorded by Koelz. This population of ciscoes from Blind Lake cannot be referred to any particular subspecies of *artedi* as described by Koelz in his key.

AGE AND GROWTH

Scales taken from the same general body region (between the dorsal fin and the lateral line) from each of the 152 ciscoes were mounted in glycerine-gelatin. Examinations for age determinations were made by the use of a projecting machine which magnified approximately thirty times. Photographs of scales from Blind Lake ciscoes are shown in Plates LX and LXI. There was no optical distortion in the image projected by this machine. For the purpose of computing the growth history of the individual fish measurements of the scale length within each annulus were made on a single scale from each fish. These lengths were taken along the longitudinal axis of the scale and directly through the focus, and were recorded to the nearest millimeter. For the computation of the length of the fish at the end of each growing season from the length of the scale within the corresponding annulus, the following direct proportional equation was employed:

$$\frac{\text{Length of scale included in annulus of year } x}{\text{Total length of scale}} = \frac{\text{Length of fish at end of year } x}{\text{Length of fish at time of capture}}$$

Van Oosten (1929), in his intensive study on the age and growth of *Leucichthys artedi* in Lake Huron, found the use of this formula to be the most satisfactory known method of computing, for a given fish, its length at the end of any previous growing season. In this formula the "length of fish at end of year x " is the unknown.

The 152 ciscoes represented eight age groups (0-VII), although the great majority (84 per cent) of the individuals belonged to three age groups, II, III, and IV (see Table II). In length they ranged from 132 to 270 millimeters standard length ($6\frac{1}{2}$ to 13 inches total length); 122 individuals (80 per cent) fell within a range of 192 to 230 millimeters standard length (9 to $10\frac{3}{4}$ inches total length). The scarcity in this collection of specimens of the 1933 and the 1934 year classes (age groups I and 0 respectively) was undoubtedly due to the fact that these fish were immature and, therefore, were not present on the spawning grounds. The smallest mesh of the experimental gill net ($1\frac{1}{4}$ -inch stretched measure) would have captured

TABLE II

LENGTH FREQUENCY DISTRIBUTION (STANDARD LENGTHS IN MILLIMETERS)
FOR EACH SEX OF EACH AGE GROUP OF BLIND LAKE CISCOES

Frequency classes of thirteen millimeters are used

Age group	Sex	Average standard length in mm.	Standard length frequencies													Total
			127 to 139	140 to 152	153 to 165	166 to 178	179 to 191	192 to 204	205 to 217	218 to 230	231 to 243	244 to 256	257 to 269	270 to 282	283 to 295	
0	Male	...	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	Female	132	1	..	..	..	..	..	..	..	..	..	..	..	..	1
I	Male	179	..	..	..	..	1	..	..	..	..	..	..	..	..	1
	Female	176	..	..	1	..	1	..	..	..	..	..	..	..	..	2
II	Male	199	..	..	..	..	2	8	4	..	1	..	..	..	..	15
	Female	198	..	..	..	..	1	5	2	..	..	..	..	..	..	8
III	Male	207	..	..	..	..	2	11	27	5	1	1	..	..	..	47
	Female	207	..	..	..	..	..	6	10	2	..	1	..	..	..	19
IV	Male	217	..	..	..	..	..	..	12	12	4	..	1	..	..	29
	Female	212	..	..	..	..	..	..	6	3	..	..	..	..	..	9
V	Male	229	..	..	..	..	..	..	1	4	..	2	..	..	..	7
	Female	235	..	..	..	..	..	..	1	..	1	..	1	..	..	3
VI	Male	239	..	..	..	..	..	..	..	3	1	3	1	..	..	8
	Female	257	..	..	..	..	..	..	..	..	1	..	..	..	1	2
VII	Male	270	..	..	..	..	..	..	..	..	..	..	..	1	..	1
	Female	...	..	..	..	..	..	..	..	..	..	..	..	..	..	...
All age groups	Male	213	..	..	..	..	5	19	44	24	7	6	2	1	..	108
	Female	207	1	..	1	..	2	11	19	5	2	1	1	..	1	44
	Both sexes	211	1	..	1	..	7	30	63	29	9	7	3	1	1	152

many of the younger fish had they been abundant. Further, several hours of observation made while spearing ciscoes during the night revealed that small ciscoes were generally scarce on the spawning ground. The dominance of Groups II, III, and IV suggests that most of the ciscoes in Blind Lake reach sexual maturity in their third and fourth years, and that after the fourth or the fifth year there is a high mortality, which is no doubt in part due to the extensive spearing carried on in the lake.

There was no significant difference in the average lengths of the

two sexes in the age groups II-V inclusive (Table II). The numbers of specimens in the other age groups are not sufficient to justify conclusions pertaining to sex differences in growth. Lengths computed from scale measurements likewise showed that males and females grow at the same rate (computed lengths by sex are not included in this paper). In a study of growth, data for both sexes may, therefore, be combined.

By using both computed and actual lengths a considerable number of data on rate of growth may be obtained from a relatively small



FIG. 15. Growth curve for Blind Lake ciscoes based on average lengths (computed and actual measured lengths) at the conclusion of each growing season, with standard lengths in millimeters and total lengths in inches. Total lengths were computed from standard lengths by using the conversion factor 1.19

collection of fish. These data for the Blind Lake ciscoes are given in Table III, and a growth curve based on the grand averages of standard lengths in millimeters, given in Table III, is presented in Figure 15. This figure also shows the growth in total length in inches.² The curve for growth in length reveals a growth tendency

² The average total lengths were computed from the averages for standard lengths by employing the conversion factor 1.19.

which is typical for cisco populations in general. There have been published results of age and growth studies on at least fifteen North American populations of *Leucichthys artedi*,³ and all reveal the same general trend of a relatively rapid growth in length during the first or the first and second years of life, with a gradual decrease in rate of growth during later years. The first prominent decrease in rate of growth is usually coincident with the attainment of sexual maturity.

TABLE III

GROWTH IN LENGTH FOR EACH YEAR CLASS, AND THE AVERAGE LENGTH OF EACH AGE GROUP OF BLIND LAKE CISCOES

The last average for each year class is based on the actual lengths of fish when collected; all other averages given in the main part of the table are based on computed lengths, and the grand averages are based on both computed and actual lengths

Year of hatching	Age group	No. of specimens	Length in millimeters at conclusion of growing season							
			1	2	3	4	5	6	7	8
1934	0	1	132	...	...	...	...	...	...	...
1933	I	3	112	177	...	...	...	...	...	...
1932	II	23	113	169	199	...	...	...	...	...
1931	III	66	112	164	189	207	...	...	...	...
1930	IV	38	105	154	182	202	216	...	...	...
1929	V	10	72	116	153	193	214	231	...	...
1928	VI	10	83	125	161	196	215	228	242	...
1927	VII	1	83	147	208	228	243	255	263	270
Grand averages			106	156	185	203	216	230	244	270
Number of specimens			(152)	(151)	(148)	(125)	(59)	(21)	(11)	(1)

A comparison of the calculated lengths at corresponding years of life as based on the different age groups (Table III) reveals that, in general, the average calculated length at any given year of life tends to become greater as the age of the fish upon which it is based decreases. This tendency is particularly strong with respect to the calculated lengths for the earlier years of life. For the ten specimens of the 1928 year class (Group VI) the average of computed lengths for fish at the end of the first year of life is 83 millimeters; for the

³ A complete summary of this literature has been given by Hile (1936a).

1929 year class (Group V) this average is 72 millimeters, but for the 1930 to the 1933 year classes (age groups IV to I) the averages of computed lengths for fish at the end of their first growing season are 105, 112, 113, and 112 millimeters, respectively. A similar increase in computed lengths, from the oldest age group to the youngest, is present for fishes at the end of their second, third, and fourth years of life. This "apparent change in rate of growth," Lee's phenomenon, has been noted by many investigators for many species of fish, and various explanations have been given to account for it. Van Oosten (1929) presented a comprehensive review of the literature pertaining to Lee's phenomenon of "apparent change in growth," and made a detailed study of the problem with respect to the lake herring or cisco *L. artedii*. He concluded that, so far as the lake herring of Saginaw Bay is concerned, this phenomenon "seems to be largely the result of perfectly natural events in the life history of the fish." He found that the herring first reaches maturity during its third, fourth, or fifth year of life, depending upon individual rate of growth; the more rapidly growing individuals of any one year class attain maturity first. It follows that the youngest year groups were represented in the catch (from the spawning grounds) only by their biggest individuals and, as older age groups were considered, more and more of those fish that had been the smaller individuals in their earlier years appeared in the older groups. Therefore the younger age groups contained a larger proportion of fast-growing fish than did the older groups and, consequently, the computed lengths for the early years of life would be greater in the younger age groups than in the older. The persistence of the phenomenon in the older age groups (in groups in which all individuals are mature) may be explained on the basis of differential mortality, that is, on the assumption that the more rapidly growing fish die off earlier in life than the more slowly growing fish.

If, as suggested by the data in Table II, most individuals of the Blind Lake population reach sexual maturity in their third and fourth years, then Lee's phenomenon, as it appears in the sample collected, might justly be explained on the basis of selection according to sexual maturity and differential mortality correlated with growth rate. Differences in growth for the different calendar years may also account in part for the phenomenon. It may be stated safely that this apparent change in growth was not due in any great

extent to errors involved in the use of the direct proportion equation for length computation, particularly since the average scale diameters within the first annulus were actually much smaller in the older fish than in the younger ones. In order to examine critically this apparent change in growth in the cisco population of Blind Lake, it would be necessary to study collections taken over a period of years.

The apparently aberrant sex ratio (108 males to 44 females) of this collection of ciscoes was probably due to the fact that males predominate on the spawning grounds during the early part of the spawning season, a phenomenon noted by Van Oosten (1929).

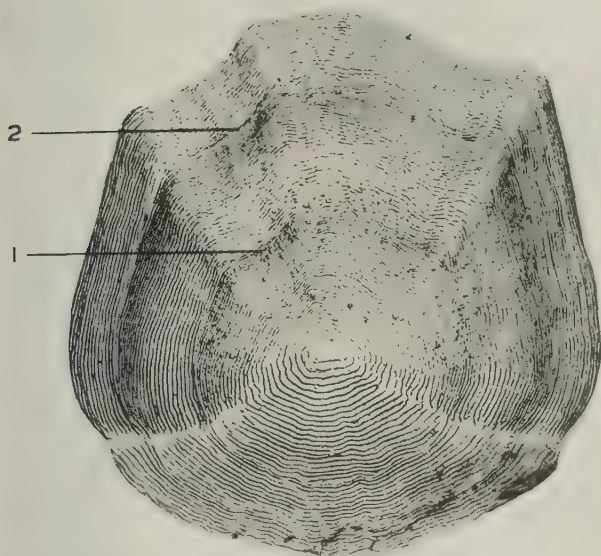
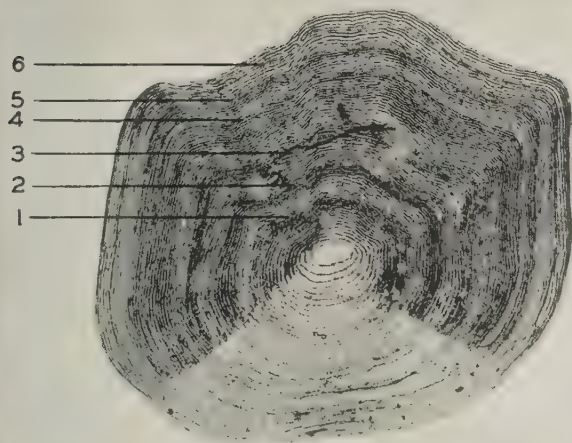
UNIVERSITY OF MICHIGAN

LITERATURE CITED

- HILE, RALPH. 1936. Summary of Investigations on the Morphometry of the Cisco, *Leucichthys artedi* (Le Sueur), in the Lakes of the Northeastern Highlands, Wisconsin. Pap. Mich. Acad. Sci., Arts and Letters, 21 (1935): 619-633.
- 1936a. Age and Growth of the Cisco, *Leucichthys artedi* (Le Sueur), in the Lakes of the Northeastern Highlands, Wisconsin. Bull. U. S. Bur. Fish., 48: 211-317, figs. 1-11.
- KOELZ, WALTER. 1929. Coregonid Fishes of the Great Lakes. Bull. U. S. Bur. Fish., 43, Part 2: 295-643, figs. 1-31.
- 1931. The Coregonid Fishes of Northeastern America. Pap. Mich. Acad. Sci., Arts and Letters, 13 (1930): 303-432, pl. 39.
- VAN OOSTEN, JOHN. 1929. Life History of the Lake Herring (*Leucichthys artedi* Le Sueur) of Lake Huron as Revealed by Its Scales, with a Critique of the Scale Method. Bull. U. S. Bur. Fish., 44: 263-428, figs. 1-43.

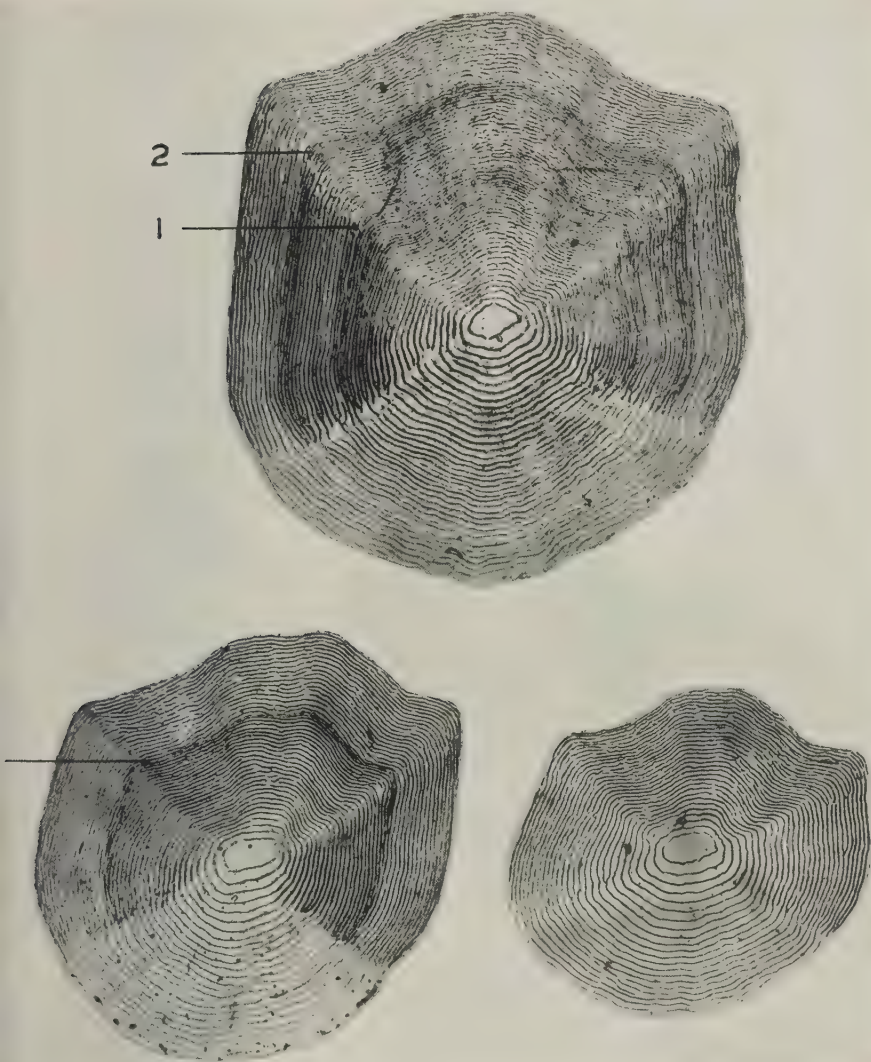
PLATES LX-LXI

PLATE LX



Scales of *Leucichthys artemi* collected from Blind Lake on December 1 and 2, 1934, after the completion of the 1934 growing season. These two scales represent: (1) a ripe female at the end of its seventh year of life (six annuli), standard length 235 millimeters, total length 11 inches; and (2) an adult male at the end of its third year of life (two annuli), standard length 233 millimeters, total length 11 inches

PLATE LXI



scales of *Leucichthys artedi* collected from Blind Lake on December 1 and 2, 1934, after the completion of the 1934 growing season. These three scales represent: (1) a spent female at the end of its third year of life (two annuli), standard length 197 millimeters, total length 9 $\frac{3}{4}$ inches; (2) an adult male at the end of its second year of life (one annulus), standard length 179 millimeters, total length 8 inches; and (3) an immature female at the end of its first year of life (no annulus), standard length 132 millimeters, total length 6 $\frac{1}{8}$ inches

THE EMBRYOLOGY OF THE SPLEEN IN *AMIA CALVA* *

HARVEY DE BRUINE

INTRODUCTION

INVESTIGATIONS on the spleen of higher vertebrates have failed to clarify many of the problems related to its embryology, to the vascularization of its pulp, to the significance and the potentialities of its first cellular components, to its relations to the reticulo-endothelial system and other lymphoid organs, to its relations to iron, calcium, fat, lipoid, and antibody metabolism, and to the effect on the animal of its removal. Many investigators have turned to the study of the spleen in lower forms in the hope of obtaining information that might aid in the correct interpretation of the organ in higher forms. In the present investigation an approach to some of these problems has been made through a study of the morphogenesis and the histogenesis of the organ in one of our fishes, *Amia calva*. The differentiation of its cell types has been followed, and an attempt has been made to interpret the findings on a functional basis.

The observations of Piper (1902*a*, 1902*b*, 1903) on the development of the spleen in *Amia* were incidental to his study of the development of the other visceral organs, and those of Robeson (1932) dealt only with hemopoiesis in the adult. Among the more recent and important papers on the spleen in other fishes are those of Jordan (1924, 1933) and of Jordan and Speidel (1924*a*, 1930, 1931), which deal with the evolution of the organ and its relation to blood-cell formation. Its histology has been described by Maximow (1923) in *Acanthias*, by Hemmeter (1926) in *Alopias vulpes*, and by Scatizzi (1932) in *Chimaera monstrosa*, and a comparative study of several forms was made by Yoffey (1929). De Gaetani (1926) described the arterial terminations in the pulp of the spleen in *Scylliorhinus canicula*. The development of the organ was first described by

* Contribution from the Department of Zoölogy of the University of Michigan and Elmhurst College.

Laguesse (1890) in *Acanthias* and *Trutta fario*. His findings have recently been confirmed by Léon (1932), who followed the history of the cell types by the use of vital stains. Numerous papers dealing with the spleen in other forms have appeared, but they will be referred to only so far as they have some bearing on the development of the organ in *Amia*. Good reviews of the literature on the spleen are given by Theil and Downey (1921), Fowler (1924), Krumbhaar (1926), Von Skramlik (1927), and others.

Thanks are due to Professor Peter Okkelberg for his advice and encouragement throughout the whole of the investigation and to Dr. Wilfrid T. Dempster, Dr. Wesley Clanton, Mr. Arnold Blaufuss, and Dr. Carl L. Hubbs for much of the material.

MATERIALS AND METHODS

The spleen and related structures were studied in approximately 170 individuals, varying in age from the time of hatching (6.5 mm. body length) to maturity. The sequence of the series up to 20 mm. varied by a millimeter or less, and those above 20 mm. by not more than 5 mm. Correlation of the different phases of splenic development with early embryonic processes proved to be impossible because of the advanced stage at which the splenic primordium makes its first appearance. Consequently total body length was chosen as an indication of age, admittedly a poor criterion, but sufficiently accurate for the purposes of this investigation.

The macroscopic structure of the spleen was studied directly from dissections and from geometrical reconstructions of serial sections. The blood vessels were injected with color masses and India ink. Injected specimens were fixed in Carnoy's II and cleared *in toto* with synthetic oil of wintergreen.

The microscopic structure was studied from section and smear preparations. The tissues were fixed in Kolmer's, Carnoy's II, Helly's, Zenker's, and Wittmaak's fluids. Most of the sections were cut at 5 microns and stained with iron hematoxylin and eosin, Mallory's triple, Wright's, or Giemsa's azure-eosin. From a group of half-grown to adult fish the following types of smear preparations of the splenic pulp were made: (1) fresh smears of cells suspended in Ringer's solution; (2) smears, fixed by drying or by formalin vapors and stained with Wright's or Giemsa's azure-eosin; (3) spleen-blood serum smears (Isaacs, 1928) made by macerating

the splenic pulp in blood serum, mounting the macerate, and then fixing and staining as in 2; (4) anatomical smears made by spreading the residue from thoroughly macerated spleen-blood serum mixtures on a slide, drying it just enough so that it would stick, and then treating the preparation as in 2. Excellent preparations of the reticulum were obtained by this method. The resulting distorted shape of the cells is an obvious disadvantage of this method, but this is compensated for by the fact that the cells, with their long cytoplasmic processes, are isolated from the pulp cells, so that the reticulum cells may be studied in their entirety instead of in fragments, as in serial sections.

MORPHOGENESIS

In this investigation Piper's (1902*a*, 1902*b*, 1903) and Robeson's (1932) observations have been confirmed in the main, but elaborated in detail and reinterpreted in the light of more recent research. For convenience of description it has seemed desirable to refer to the various stages of splenic development as "the long mesenchyme bed," the "club-shaped spleen," and the "hooked spleen."

The Long Mesenchyme Bed

The splenic primordium appears first in larvae of about 7.5 mm. body length as an elongated band of mesenchyme following the course taken by the subintestinal vein. The anterior end lies on the left side of the intestine, and it spirals ventrally so that its posterior end lies on the right side of the gut. The main axis of the primordium makes an angle of about 40° with the mid-sagittal body plane. Before the larvae are 10 mm. in body length, the exact limits of the splenic area are rather indefinite; however, the primordium becomes conspicuous by a condensation of its mesenchyme and an accompanying increase in the mitotic divisions of its cells. The splenic primordium lacks an arterial supply at this early age (Pl. LXII, Fig. 1), and its vascularization is entirely venous in character. The original subintestinal vein has differentiated into the anterior (dorsal) and the posterior (ventral) intestinal veins and the newly developed splenic vein joins the latter along the posterior third of the splenic primordium. No secondary branches leading from the splenic primordium are noticeable at this age.

The Club-Shaped Spleen

In larvae between 12 and 13 mm. body length there occur a more pronounced condensation and a localization of the splenic primordium. This change is characterized by a marked increase in the number of cells in the spleen. The general development, however, takes on a different aspect. In the earlier stages there was a crowding of the increasing number of mesenchyme cells into a more limited space, but now the spleen is beginning to change its shape by localized growth, finally resulting in a reduction in the total length of the organ. The change in the shape of the splenic primordium from a long mesenchyme bed to a shorter, thicker, and more condensed form (Pl. LXII, Fig. 2) suggests the "club-shaped" spleen of Piper's descriptions, and I have adopted this designation. The two ends are heavier than the central region, and the anterior end is slightly larger than the posterior. As a result of the bending of the intestine, the organ becomes relatively straight. In position it is almost parallel to the axis of the intestinal spiral and the mid-sagittal plane of the body; however, its anterior end lies at a more ventral level (about 40°) than its posterior end. The organ as a whole has begun to separate from the intestinal wall, and it may now be considered an independent constituent of the viscera. During the progress of this separation an omental connection is retained along the whole length of the organ.

At this age all the fundamentals for the vascularization of the spleen are definitely formed, but the actual blood supply of the organ is still principally venous in character. The splenic vein receives a few secondary branches from within the organ, but the splenic artery, which has differentiated and lies parallel to the vein, is without secondary vessels penetrating the organ (Pl. LXII, Fig. 2). The intestinal vessels of this region lie in the omentum, and in some cases they appear to follow the organ during its separation from the intestine, but this relationship is only a temporary one.

The Hooked Spleen

In larvae 13.5 mm. in length there is an approach to conditions as they are found in the adult. The general shape of the spleen may be described as "hooked" (Pl. LXII, Fig. 3). The bending of the intestines to form the first complete loop and the accompanying

torsion or twisting have brought the hooked spleen from a position ventral to the intestinal tract, to a position just dorsal to the junction of the large and small intestines. Its main axis, which was formerly more or less parallel to the axis of the intestinal spiral, is now plainly perpendicular to the latter. The spleen has also shifted in its relations to the mid-sagittal plane, and the anterior end now lies to the right. The anterior half of the organ is predominantly larger; its tip is bending to the left and ventrally. The posterior half remains slender, and its tip also bends ventrally, thus maintaining its original relationship to the inner curvature of the spiraling intestine. The omental support of the hooked spleen is narrowing down and is attached to only the anterior and central regions of the spleen.

The major blood vessels of the splenic region lie in the intestinosplenic omentum. The posterior intestinal arteries and veins approach the central region of the spleen, but the splenic artery and vein are very closely associated with the posterior lobe of the spleen. The splenic artery may have two to four secondary branches penetrating the splenic tissue, and the vein may receive as many as fifteen secondary branches from the spleen.

In the 14.5 mm. larva the position and the shape of the spleen are the same as in the adult. Figure 4 (Pl. LXII) represents these definitive conditions. With continued looping of the intestine the anterior end of the spleen is carried to the left again, so that its major axis now lies almost parallel to the mid-sagittal body plane. The organ as a whole lies just anterior and dorsal to, and is closely attached to, the junction of the large and small intestines. This position is retained throughout the life of the animal. The anterior end of the organ has grown considerably both toward the right and ventrally. It constitutes the anterior lobe and has not been observed to subdivide further into lobules. With its increase in size it becomes plainly visible in a ventral view of the visceral organs, where it lies just anterior to the intestinal junction, and posterior and ventral to the posterior tip of the cardiac stomach. Similarly, the posterior tip of the spleen, or posterior lobe, is visible ventrally, even though it lies back of the interintestinal omentum and within the posterior intestinal curvature. The central sector, or middle lobe, is characterized by a hilum along its left ventral edge. It retains its close relations to the intestinal junction by the attachment of the intestinosplenic omentum, which is confined to the hilum.

At this stage (Pl. LXII, Fig. 4) the original splenic artery and vein join the posterior intestinal artery and vein at right angles at the hilum and have become incorporated within the organ. Secondary branches increase in number by constant subdivision, but no characteristic plan of arrangement can be recognized among them.

Discussion of Morphogenesis

The position of the spleen in the adult *Amia* must be considered extraenteric as described by Jordan (1924). This is similar to the conditions found in elasmobranchs, other ganoids, and teleosts. During development there is a constant change in position with increasing age. The long mesenchyme bed and the club-shaped spleen lie ventral to the intestinal tract, but the hooked spleen lies dorsal to it. These changes are not the result of the movements or of the migration of the spleen itself, but of the twisting and looping of the intestinal tract. The position of the long mesenchyme bed is determined by the course of the subintestinal vein, while the positions of the club-shaped and the hooked spleens are determined by the attachment of the intestinosplenic omentum and its relations with other visceral organs. The anterior lobe of the hooked spleen, as in the adult, is crowded ventrally by the posterior tip of the stomach. More posteriorly the intestinal loop forces the posterior lobe of the spleen into the small space between the large and the small intestines just posterior to their junction, and consequently its chance for free growth is limited.

The vascularization of the spleen described for each of its phases of development must be interpreted in the light of conditions as they are found in the adult. In general, the vessels may be designated as forming the extrinsic and the intrinsic systems. The former includes the vessels that are found near the hilum and outside the organ, namely, the posterior intestinal arteries and veins (Pl. LXII, Fig. 4), and these veins include those which are incorporated within the organ and enter at the hilum, namely, the splenic arteries and veins with their primary, secondary, and tertiary branches. The development of the arteries is not synchronized with the development of the veins in the early stages. The details of this process will be discussed later.

HISTOGENESIS OF THE SPLEEN IN *AMIA CALVA**The Origin of the First Cellular Components*

The first cells that contribute to the formation of the splenic primordium may easily be traced back to the mesenchyme cells along the outer wall of the subintestinal vein. However, in larvae between 6 and 7.5 mm. body length the mesenchyme has not yet invaded this area (Pl. LXIII, Fig. 1). At this stage the coelomic epithelium consists of a fairly distinct single layer of cells. The nuclei of its cells are round to oval, and slightly larger than those of the mesenchyme cells. The peri-intestinal mesenchyme is a homogeneous loose-celled tissue clearly set off from the intestinal epithelium by a distinct basement membrane. The nuclei of the tissue are round to oval in section and may each contain one or two nucleoli; the cytoplasm is slightly granular, and cell membranes are indistinguishable. The beginnings of the subintestinal vein may be recognized by its differentiating endothelium, which is clearly defined only on the proximal surface of the vessel. On the distal surface the endothelium is incomplete, and there is free communication between the lumina of the differentiating vein and that of the venous yolk plexus. The young blood cells in the vessel have presumably been derived from the blood islands on the surface of the yolk mass.

In larvae between 8 and 9 mm. in length the peri-intestinal mesenchyme, from which the splenic primordium originates, has just begun to differentiate in the area between the coelomic epithelium and the endothelium which forms the distal wall of the vein (Pl. LXIII, Fig. 2). The nuclei of these cells are smaller and less conspicuous than those of the neighboring mesenchyme cells, and their cytoplasm is relatively clear and completely fills the interspaces. Irregular masses of the cells may project into the lumen of the vein in the regions where the endothelium is still incomplete. The coelomic epithelium is now a distinct layer, and forms a complete covering for the early splenic primordium.

The Long Mesenchyme Bed

The coelomic epithelium, the primordium of the capsule, changes very little during this stage, except that the nuclei seem to project more prominently into the coelomic cavity, giving a pebbled effect to the surface of the organ (Pl. LXIII, Fig. 3). The mesenchyme

cells multiply actively by mitosis to form the pulp, the most conspicuous part of the organ. The great majority of its cells have very lightly stained and inconspicuous nuclei. These seem to be differentiating into the reticular tissue of the pulp. A few other cells, having large, oval, slightly reticulated nuclei with a moderate amount of basophilic cytoplasm, apparently are young stages of the erythrocyte series or lymphomyeloid hemoblasts, as described by Robeson (1932) in the adult *Amia*.

At this time small irregular clear spaces begin to appear between the mesenchyme cells. These tissue spaces or lacunae increase in size by a pushing back of the neighboring cells. The cells on their surface tend to flatten and form a pseudoendothelial lining. Several adjacent lacunae have been observed to fuse into larger lacunar spaces. Occasionally a hemoblast migrates into the lacunar space and immediately matures into an erythrocyte.

The endothelial lining of the subintestinal vein remains essentially as in earlier stages. Occasional hemoblasts from the splenic pulp enter the lumen of the vessel along its distal wall, where the endothelium is still incomplete.

The Club-Shaped Spleen

This stage in splenic histogenesis (Pl. LXIII, Fig. 4) is characterized by a continuation of lacunar differentiation in the pulp, by fusion of the lacunae to form more extensive sinusoidal spaces, and by the fusion of some of these spaces with the lumen of the splenic vein. This fusion occurs in the regions where the distal endothelial wall is not completed by a true endothelial lining and is a significant phase in splenic development because it results in the establishment of a communication between the deeper parts of the splenic pulp and the general venous circulation. The splenic artery, which has differentiated, lies in the peri-intestinal mesenchyme, but has no branches extending into the pulp (Pl. LXIII, Fig. 4). It contains blood cells, and its endothelial lining is very distinct. It differentiates by an apical growth of its tip, which penetrates between the mesenchyme cells.

In this stage a new type of cells is differentiating from a few of the mesenchyme cells of the pulp. They are considerably larger than other cells, their cytoplasm contains acidophilic granules, and their nuclei are spherical and have a lightly reticulated chromatin

network. They resemble the early stage of an eosinophil as described by Robeson (1932).

Another change which is begun at this age is the deposition of isolated masses of dark brown granular pigment in the splenic pulp. Each of these masses is composed of from 30 to 50 granules. These, however, are not peculiar to the splenic tissue, but appear in the body wall and other organs as well.

The Hooked Spleen

In the development of the splenic capsule its outer component, the single layer of mesothelial cells derived from and continuous with the peritoneum, remains almost unchanged. It covers the entire organ except at the hilum. Growth of the organ, however, has resulted in a stretching of these cells, so that they form a layer only 4 to 6 microns in thickness, with nuclei appearing spindle-shaped in sections. In larvae of 16 to 20 mm. body length there is a differentiation of the mesenchyme cells beneath the visceral mesothelium to form the second component of the capsule, namely, the collagenous connective tissue layer. Its fibrils take on a bluish color in Mallory's triple connective tissue stain. Their differentiation continues until the larvae are about 50 mm. in length, when the adult condition seems to be established. The whole fibrous layer may vary in thickness from 6 to 10 microns. It is difficult to make out the limit of its inner surface, since the underlying reticulum is attached to and is continuous with it. The reticulum in these peripheral regions of the pulp is comparatively coarse, and when studied in sections shows some clear spaces. These probably belong to a system of subcapsular lymph channels. No muscle cells have been observed in any stage of capsular development.

The differentiation of the pulp of the hooked spleen into the two major regions described by Robeson (1932) in the adult spleen, namely, the white pulp or lymphoid cords which follow the course of the main blood vessels, and the red pulp or myeloid tissue which fills in all the interspaces, does not become apparent until the fish is almost half grown. In the earlier stages, 14.5 mm. larvae, only the red pulp or myeloid tissue exists. It consists of a basic framework of mesenchymatous cells, which retain their embryonic characteristics until the larvae are about 17 to 20 mm. long. Then those cells which are destined to become part of the permanent framework

of the pulp differentiate. This change can be detected in the appearance of collagenous fibrils in their cytoplasm, similar to those described for the capsule, but in the 25 mm. larvae it is found throughout the pulp as in the adult (Pl. LXIV, Fig. 1). It should be noted that this true reticulum is the supporting framework for the pulp, and its component strands of tissue make a veritable meshwork or net, in the meshes of which the free elements of the pulp are lodged. There is no evidence of the trabecular development which is characteristic of the spleens of higher vertebrates. The undifferentiated mesenchyme cells which retain their embryonic characteristics have been interpreted by various investigators (Laguesse, 1890; Jordan and Speidel, 1930; and others) as stem or mother cells of the future hemoblasts and especially of the lymphocytes.

Multiplication of the hemoblasts by mitosis and their differentiation into all types of blood cells continues as in the earlier stages. Erythropoiesis proceeds at the normal rate, and the great increase in the number of mature erythrocytes in the interstices of the reticulum can be accounted for only by the establishment of an arterial supply to the splenic pulp (to be described later) and an influx of these cells from the general circulation. Leucopoiesis, or the formation of granulocytes, as they are named by Robeson (1932), continues in part in the pulp. The eosinophils especially are more numerous and conspicuous in the lumina and walls of the veins, the peri-intestinal mesenchyme, and the omentum. Evidence seems to indicate that their progenitors are the large cells found in the lumen of the splenic vein of the club-shaped stage. The special granulocytes, which originate from the granuloblasts, tend to remain in groups of three to six in the pulp. Many contain ingested erythrocytes and pigment granules indicating phagocytic activity. Basophils are also present. They are very heavily granulated and may also contain remnants of the red blood cells. Eosinophils with bacillary granules, monocytes, and thrombocytes, described by Robeson (1932) from the blood stream of the adult, could not be identified in the developing splenic tissue.

The masses of brown pigment, which first appeared in the club-shaped spleen, form a third component of the red pulp. These masses increase in number and size, and may at this stage contain 50 to 100 granules each. Their relations to any of the splenic cells remain obscure and no satisfactory explanation of their origin could

be obtained. They resemble closely the pigment found in other parts of the body.

The lymphoid regions of the pulp do not become apparent until the young fish is at least 150 mm. long. Then great numbers of both the large and the small lymphocytes appear as isolated nodules near some of the smaller blood vessels. These masses grow and fuse with one another, so that in the adult spleen about half of the pulp is lymphoid in character. According to Robeson (1932), the small lymphocytes are derived from the larger type. Jordan (1933) contends that in teleosts they may differentiate into other types of blood cells after entering the blood stream and that both types originate from the hemoblasts. This contention holds for the young *Amia* as well. In sections of the spleen the lymphocytes are very abundant, but the number of cells in mitosis is very small; consequently local division can scarcely account for their great numbers.

During the development of the blood vessels in the hooked spleen the veins remain quite independent of the arteries, although the major intrinsic vessels, the splenic artery and vein, lie parallel to each other in the hilar region. In the pulp no constant plan of arrangement has been recognized among their branches.

The early development of the intrinsic venous trunks has been traced to the sinusoids of the club-shaped spleen. In the hooked spleen the structure of the vessels characteristic of the adult is soon established. The larger venous trunks, in the spleens of larvae 15 to 18 mm. long, acquire a definite endothelial lining which differentiates directly from the flattened and exposed mesenchyme cells. At the same time some of the underlying mesenchyme cells differentiate into a thin layer of supporting connective tissue with collagenous fibrils such as has been described for the capsule. In the half-grown fish a thin layer of circular, smooth muscle fibers appears between the endothelium and the fibrous connective tissue layer to complete the structure of the larger intrinsic veins. The terminations of the veins in the pulp resemble the embryonic conditions in that the endothelium gradually blends into the reticulum and the lumina remain in direct communication with the open spaces or the venous sinuses of the pulp (Pl. LXIV, Fig. 2). Openings, or stomata, of this type also occur in the sides of some of the smaller venules.

The important histogenic feature of the hooked spleen is the establishment of an arterial supply to the pulp. In the 13.5 mm.

larvae the first two branches of the splenic artery penetrate the pulp from the outside and enter at the hilum. They appear to have a growing tip which forces aside the mesenchyme and free elements of the pulp. It is interesting to note that an erythrocyte usually lies within the tip of the growing point and probably aids in expanding the lumen. The mesenchyme cells along its path differentiate to form the fibrous connective tissue layer of the vessel. At the hilum the fibrous layer is continuous with the connective tissue of the main extrinsic artery and the splenic capsule. It has been called the hilar sheath by Whiting (1897). Collagenous fibrils, which become continuous with those of the reticulum, appear in its cells in the 17 mm. larvae. In the adult the fibrous layer is ten to twenty times as thick as the corresponding layer of the veins. In the half-grown fish circular and longitudinal muscle fibers appear in the walls of the larger arteries, but their development was not followed.

The terminations of the intrinsic splenic arteries in the pulp are different from the veins because they develop as a closed system of tubes; hence some means other than the usual capillary system is devised to complete the vascular circuit. Soon after the vessels have penetrated the pulp, in 13.5 to 20 mm. larvae, they branch and rebranch irregularly to form arterioles. These arterioles lack the muscular layer, and their lumina are about 15 to 20 micra in diameter. In the 25 to 50 mm. larvae two to four thick masses of the mesenchyme cells radiating from the ends of the arterioles tend to become clear of all cytoplasmic granules, and their nuclei stain lightly. The blood cells are pushed aside, since a small branch of the arteriole grows into each of these regions. The arterial ends are ellipsoids (Pl. LXIV, Fig. 3). Within the ellipsoids the endothelium blends with the reticulum and loses its characteristics as a lining membrane. The lumina remain very narrow, and the distal ends come into direct communication with the open sinusoid spaces of the pulp. Later disintegrating erythrocytes and isolated pigment granules are frequently found in the walls of the ellipsoids. Yoffey (1929) and Scatizzi (1932) both claim to have found deposits of lipid granules in the ellipsoids. Figure 3 (Pl. LXIV), taken from the spleen of the adult, shows a branch of an arteriole and the major part of three ellipsoids. In the lower ellipsoid the open communication with the pulp spaces is apparent. In the upper ellipsoid a degenerating erythrocyte can be seen. The final result is the estab-

ishment of an open vascular circuit through the splenic pulp and an influx of blood cells, especially erythrocytes, from the general circulation into the open meshes of the reticulum.

Discussion of Histogenesis

There has been some difference of opinion regarding which germ layer gives rise to the spleen, and the controversy has centered principally around the spleen of ganoids. There are those who believe in an entodermal origin, whereas others maintain that the origin is entirely mesodermal. The literature on this subject has been summarized by Thiel and Downey (1921). My observations on the development of the spleen in *Amia* lead me to agree with those who maintain that the organ is of mesodermal origin, and they confirm especially the conclusions reached by Piper (1902a, 1902b, 1903), who worked on the same form. The splenic primordium in *Amia* takes its origin from the mesenchyme along the outer wall of the subintestinal vein. Piper referred to this fundament as the long mesenchyme bed. This terminology I have adopted. Léon (1932) holds that the vascular endothelia give rise to splenic mesenchyme. In *Amia* the evidence indicates that there is a migration of the perintestinal mesenchyme into the potential splenic region and that this is followed by a rapid proliferation of the mesenchyme cells, some of which differentiate into endothelial cells, quite in contrast to the view held by Léon.

With regard to the splenic capsule, my observations indicate that its two main components, the mesothelium and the underlying collagenous fibrous connective tissue, each arise from different sources. The former is continuous with and derived from the coelomic epithelium. It remains as a thin single-layered epithelium and in the adult appears as a smooth glistening peritoneal covering in every way similar to that of the other visceral organs. The fibrous layer is a derivative of the mesenchyme of the pulp and develops considerably later (18 mm. larvae). Laguesse (1903) made an extensive study of the development of the capsule in *Acanthias*, and came to the conclusion that the collagenous fibrils of the capsule originated as a hyalinization and a solidification of some precollagenous material in the mesenchyme cells. A study of sections of the spleen of *Amia*, which were stained with Mallory's triple connective tissue stain, indicates that the conclusion reached by Laguesse is correct. This

transformation, which takes place gradually, begins in certain peripheral or subcapsular regions of the organ and around the larger blood vessels and then spreads slowly through the entire pulp. In successively older stages the affinity for the aniline blue increases both in intensity of the stain and in amount of material stained. This process occurs simultaneously with the penetration of the arteries into the pulp, but it is doubtful whether there is any physiologic relation between the two processes, since the arteries are closed tubes at this time and the blood does not have a free circulation through the pulp.

Whiting (1897) called the thick layers of connective tissue surrounding the main intrinsic arteries an involuted hilar sheath. He believed that this sheath was derived directly from the capsule of the organ, and he placed considerable emphasis upon this interpretation. My study of this layer in *Amia* indicates that it develops *in situ* and that there is no involution of the capsule to form it. It is continuous with the capsule, but it is also continuous with the homologous layer in the extrinsic part of the artery. However, Whiting was correct in his suggestion that the major blood vessels do offer some support for the pulp through their relations with the reticulum.

The major regions of the splenic pulp in fishes are generally described as the white or lymphoid regions and the red pulp or Billroth cords. Yoffey (1929), working on the spleen of elasmobranchs, describes three regions, namely, the lymphoid, the pulp, and the ellipsoids. Most earlier workers considered the ellipsoids a part of the arterial system. Hemmeter (1926), in his study of *Alopecias vulpes*, speaks of them as hemolytic islands. In the adult *Amia* the ellipsoids are directly connected with the ends of the arterioles; however, in development they are derived from the mesenchyme cells and acquire their relations to the arteries secondarily. Yoffey's interpretation of them as separate regions in the splenic tissue is correct, but of little significance.

A study of the cell types found in the splenic pulp involves a careful analysis of questions relating to hemopoiesis, cell lineage, hemolysis, pigment formation, and differentiation of mesenchyme cells. It is beyond the scope of this investigation to consider blood-cell formation and destruction in detail, but a few general observations have been included in the light of Robeson's description (1932)

of hemopoiesis in the adult *Amia*. Most of his interpretations, so far as they involve the spleen, have been substantiated.

An interesting observation has grown out of the comparison of the erythroblasts found in the ordinary anatomical smear preparations with those found in spleen-blood serum smear preparations. In the latter the erythroblasts respond by maturing into erythrocytes and also by entering into mitosis. There apparently is some stimulus in the latter treatment which calls forth these responses. Jordan and Speidel (1924*b*) concluded from their studies on intravascular maturation of the erythroblasts that the necessary stimulus was contact with the blood stream and a lower carbon dioxide concentration. It is possible that similar conditions may be operative in the spleen-serum technique.

An analysis of the development of the early mesenchymal cells indicates that these must be interpreted as the polyvalent parent cells of the various elements of the splenic pulp. Evidence for this has been presented, and it has been shown that they may differentiate into endothelial, reticular, hemoblast, and ellipsoidal cells and that they may also produce pigment. The parent cells do not display any characteristics by which their subsequent fate might be determined. They divide actively to produce more cells of the same kind even in the adult spleen or they may differentiate at any time into the definitive types. This view is also supported by Jordan in several recent publications, and he goes a step further by contending that the lymphocytes are the mother cells for all types of blood cells.

I can add little to the question of the origin of splenic pigmentation. General observation indicates that there are two types of pigment. The isolated dark brown granular masses first observed in the club-shaped spleen may be secretion products of certain cells of the splenic pulp. The other type of pigment is found in the cells of the ellipsoids and in certain granulocytes. Krumbhaar (1926), Yoffey (1929), Scatizzi (1933), and others have presented clinical and experimental evidence which indicates that these granules may be disintegration products of hemolysis of the senile erythrocytes. In *Amia* these granules and decomposing red blood cells are found in the granulocytes and in the ellipsoids at the same time.

The development of the blood vessels supplying the spleen in *Amia* indicates that there is a close functional relationship between

the organ and the vascular system. The vessels enter the hilum and branch extensively to supply the pulp, where they form an "open" circulation through the meshes of the reticulum. Thiel and Downey (1921) have given an accurate summary of the conflicting opinions regarding the terminations of the finer vessels within the spleen of various vertebrates. Modern investigators such as Krumbhaar (1926), De Gaetani (1926), Tait (1927), Yoffey (1929), McNee (1931), and Scatizzi (1932) all have come to the conclusion that an "open" circulation exists through the splenic pulp in fishes, a conclusion to which the earlier workers were not reconciled.

The intrinsic splenic veins begin their development about the same time that the splenic primordium first appears. Their differentiation proceeds from within the splenic pulp, and involves the formation of lacunar spaces and their fusion to form sinusoids. These processes take place in the long mesenchyme bed, but the union of the larger sinusoids with the lumen of the subintestinal vein does not take place before the stage of the club-shaped spleen. The differentiation of the mesenchyme cells into the endothelial and the connective tissue layers of the larger vessels is not completed before the stage designated as the "hooked spleen." Their differentiation is similar to that described by Laguesse (1890) in his study of the developing spleen of *Trutta fario* and recently confirmed by Léon (1932).

That the arteries penetrate the organ from the outside is an important embryological feature and quite in contrast to the development of the veins which grow from within the pulp toward the hilum. Similar observations were made by Tait (1927) in *Acanthias*. It is also of importance that the arteries begin as a closed system of tubes, which later acquire open terminations by way of the ellipsoids. It has not been possible to discover how the penetration is effected, but the possibility may be suggested that the growing tip of the artery may have some digestive action on the tissues penetrated, or perhaps the penetration results from a pressure on the inside of the arterial ends. It is also significant that the arterial supply of the spleen is established much later in the development than the venous supply. The fact that the splenic artery remains relatively small as compared with the vein is of importance. It emphasizes the venous origin of the spleen, and the arrangement allows for a lower blood pressure, and a slower current in the sinusoidal

spaces of the pulp, and also provides for a convenient storage place for all types of blood cells as well as an excellent locus for hemopoiesis and hemolysis. The strategic position of the ellipsoids with their hemolytic and phagocytic powers is of significance in connection with the elimination of undesirable substances that might enter the splenic pulp from the general circulation.

SUMMARY

1. The critical stages in the morphogenesis of the spleen of *Amia calva* have been described as the long mesenchyme bed, the club-shaped spleen, and the hooked spleen.

2. The splenic primordium originates in about the 7.5 mm. larva from the peri-intestinal mesenchyme along the outer wall of the subintestinal vein. During morphogenesis, changes in its position result from the twisting and looping of the intestinal tract. In the adult the organ occupies an extraenteric position, and is supported by the intestinosplenic omentum from the junction of the large and the small intestines.

3. The extrinsic and the intrinsic vascularizations of the spleen have been described. The veins of the splenic pulp are formed early in life through the formation of lacunae, the fusion of adjacent lacunae to form sinusoids, and the subsequent fusion of the sinusoids with the lumen of the splenic vein. The endothelial, muscular, and connective tissue cells which compose the walls of the veins are derived from the mesenchyme cells of the pulp. In the hooked spleen the arteries penetrate the pulp at the hilum as closed branches from the splenic artery, and they open into the pulp through the ellipsoids secondarily. An "open" circulation in the pulp has been demonstrated. The ellipsoids are derived from the mesenchyme cells of the splenic pulp and function as valves controlling the arterial supply to the pulp and also as phagocytic centers.

4. The major regions represented in the splenic pulp are the myeloid and the lymphoid. The histogenesis of the mesenchyme cells has been traced into the reticulum, endothelium, hemoblasts, and ellipsoids, and they probably give rise to pigment. In the hooked spleen the reticulum composes the major supporting framework of the pulp, in the interstices of which are many free cells, such as hemoblasts, erythroblasts, granuloblasts, erythrocytes, granulocytes, and pigment granules.

5. Throughout life the spleen is active in hemopoiesis and hemolysis, and as a storage place for all types of blood cells.

6. The capsule has a double origin from the coelomic epithelium and the mesenchyme. No muscle fibers have been observed in it, but these are present in the walls of the larger blood vessels. There is no evidence of trabecular development.

UNIVERSITY OF MICHIGAN

LITERATURE CITED

- DE GAETANI, L. 1926. Sui corpuscoli periarteriosi terminali nella milza dei Selaci. *Arch. Ital. di Anat.*, 23 : 321-339.
- FOWLER, R. H. 1924. Comparative Anatomy of the Spleen. *Western Medical Times*, 44 : 1-3, 27-36, 116-122, 158-162, 205-228, 247-248, 267-269, 361-370, 400-406.
- HEMMETER, J. C. 1926. The Special Histology of the Spleen of *Alopecias vulpes* and Its Relation to Hemolysis and Hematopoiesis. *Zeitschr. f. Zellforsch. u. mikr. Anat.*, 3 : 329-345.
- ISAACS, R. 1928. Alterations of Tissue Cells in the Blood Stream. *Science*, 68 (No. 1770) : 547-548.
- JORDAN, H. E. 1924. The Significance of the Spleen in the Light of Embryological, Evolutionary and Experimental Data. *Virginia Medical Monthly*, 51 : 537-544.
- 1933. The Evolution of the Blood-forming Tissues. *Quart. Rev. Biol.*, 8 : 58-76.
- AND SPEIDEL, C. C. 1924a. Studies on Lymphocytes. II. Origin, Function and Fate of the Lymphocytes in Fishes. *Journ. Morphol.*, 38 : 529-549.
- 1924b. The Fundamental Erythrocytopoietic Stimulus. *Proc. Soc. Exper. Biol. and Med.*, 21 : 399-404.
- 1930. Blood Formation in Cyclostomes. *Am. Journ. Anat.*, 46 : 355-391.
- 1931. Blood Formation in the African Lungfish, under Normal Conditions and under Conditions of Prolonged Estivation and Recovery. *Journ. Morph. and Physiol.*, 51 : 319-371.
- KRUMBHAR, E. B. 1926. Functions of the Spleen. *Physiol. Rev.*, 6 : 160-200.
- LAGUESSE, E. 1890. Recherches sur le développement de la rate chez les poissons. *Journ. d'anat. et physiol. Paris*, 26 : 345-406, 425-495.
- 1903. Sur l'histogénèse de la fibre collagène et de la substance fondamentale dans la capsule de la rate chez les Sélaciens. *Arch. anat. microsc.*, 6 : 99-169.
- LÉON, C. 1932. Histogénèse de l'ébauche splénique chez les Salmonides. *Arch. anat. microsc.*, 28 : 363-397.

- McNEE, J. W. 1931. The Spleen: Its Structure, Functions and Diseases. Trans. Microsc. Soc. London, 54: 185-236.
- MAXIMOW, A. 1923. Untersuchungen über Blut und Bindegewebe. X. Über die Blutbildung bei den Selachiern in erwachsenen und embryonalen Zustände. Arch. mikr. Anat., 97: 623-717.
- PIPER, H. 1902a. Die Entwicklung von Leber, Pankreas, Schwimmblase und Milz bei *Amia calva*. Anat. Anz. (Verh. Anat. Ges.), 1902, S. 18-25.
- 1902b. Die Entwicklung von Magen, Duodenum, Schwimmblase, Leber, Pankreas, und Milz bei *Amia calva*. Arch. Anat. u. Physiol. (Anat. Abt.), Suppl., 1902, S. 1-87.
- 1903. Berichtigung zu meinen Aufsatz: Die Entwicklung von Magen, u.s.w., und Milz bei *Amia calva*. Ibid., 1903, S. 27-28.
- ROBESON, J. M., Jr. 1932. Hemopoiesis in *Amia calva*. Zeitschr. f. Zellforsch. u. mikr. Anat., 16: 305-313.
- SCATIZZI, I. 1932. La milza di *Chimaera monstrosa*. Arch. Ital. di Anat., 29: 560-587.
- SKRAMLIK, E. VON. 1927. Die Milz. Mit besondere Berücksichtigung des vergleichendes Standpunkt. Ergebn. d. Biol., 2: 505-553.
- TAIT, J. 1927. A Review of the Structure and Function of the Spleen. Brit. Microsc. Journ., 2: 291-295.
- THIEL, G. A., AND DOWNEY, H. 1921. The Development of the Mammalian Spleen, with Special Reference to Its Hematopoietic Activity. Am. Journ. Anat., 28: 279-339.
- WHITING, A. J. 1897. On the Comparative Histology and Physiology of the Spleen. Trans. Roy. Soc. Edinburgh, 38: 253-316.
- YOFFEY, J. M. 1929. A Contribution to the Study of the Comparative Histology and Physiology of the Spleen, with Reference Chiefly to Its Cellular Constituents. I. In Fishes. Journ. Anat., 63: 314-344.

ABBREVIATIONS USED IN PLATES

A.I.A. — Anterior intestinal artery	P.I.V. — Posterior intestinal vein
A.I.V. — Anterior intestinal vein	P.I.V.D. — Posterior intestinal vein, dorsal
Duo. — Duodenum	P.I.V.V. — Posterior intestinal vein, ventral
H.P.V. — Hepatic portal vein	P.M.A. — Posterior mesenteric ar- tery
Int. — Intestine	S.Int. — Small intestine
L.Int. — Large intestine	S.I.V. — Subintestinal vein
Mes.V. — Mesenteric vessels	Sp. — Spleen
Pan. — Pancreas	Sp.(A.L.) — Spleen (anterior lobe)
P.Gas.A. — Posterior gastric artery	Sp.(M.L.) — Spleen (middle lobe)
P.Gas.V. — Posterior gastric vein	Sp.(P.L.) — Spleen (posterior lobe)
P.I.A. — Posterior intestinal artery	Sp.A. — Splenic artery
P.I.A.D. — Posterior intestinal ar- tery, dorsal	Sp.V. — Splenic vein
P.I.A.V. — Posterior intestinal ar- tery, ventral	

EXPLANATION OF PLATE LXII

Figures 1, 2, 3, and 4 have been drawn from geometrical reconstructions of parts of the viscera of *Amia* larvae at the body lengths indicated. The arrows above and below each figure indicate the mid-sagittal body plane. All represent the dorsal view. The mesenteries and the omenta have been omitted for purposes of clarity. Part of the intestinal tract has been omitted to show the underlying splenic primordium.

FIG. 1. The long mesenchyme bed of an 11 mm. larva

FIG. 2. The club-shaped spleen of a 12.5 mm. larva

FIG. 3. The hooked spleen of a 13.5 mm. larva

FIG. 4. The hooked spleen of a 50 mm. larva. This closely approximates the adult position, the shape, and the vascularization of the organ

PLATE LXII

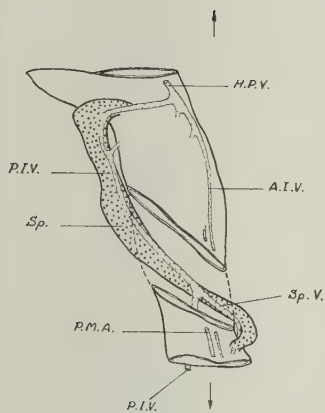


FIG. 1

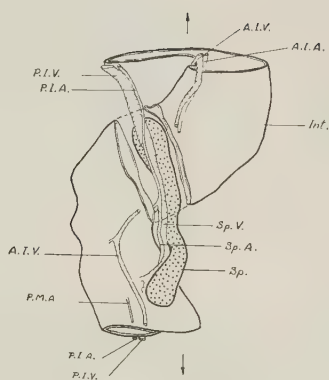


FIG. 2

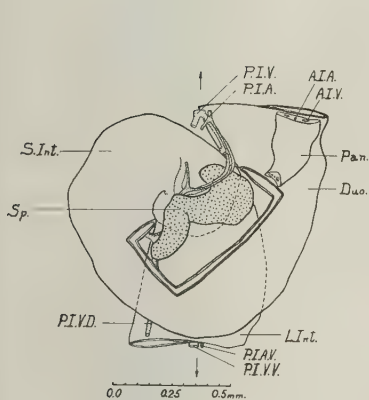


FIG. 3

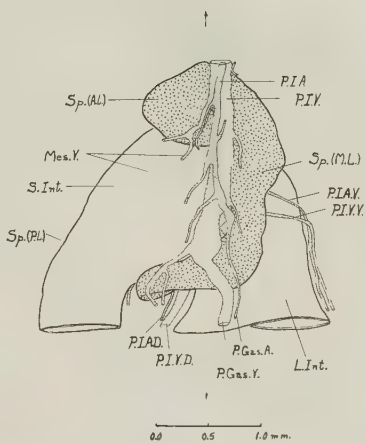


FIG. 4

EXPLANATION OF PLATE LXIII

- FIG. 1. Photomicrograph of a cross section through the intestine of a 6.5 mm. larva. The peri-intestinal mesenchyme has not yet invaded the region where the splenic primordium will develop, and the lining of the subintestinal vein is not yet a distinct membrane
- FIG. 2. Photomicrograph showing invasion of peri-intestinal mesenchyme between coelomic epithelium and subintestinal vein from which the splenic primordium will arise. 8 mm. larva
- FIG. 3. Photomicrograph of cross section through the long mesenchyme bed. 10.7 mm. larva, showing fusion of the lacunae and some hemoblasts
- FIG. 4. Photomicrograph of a cross section through the club-shaped spleen. 12.7 mm. larva

PLATE LXIII

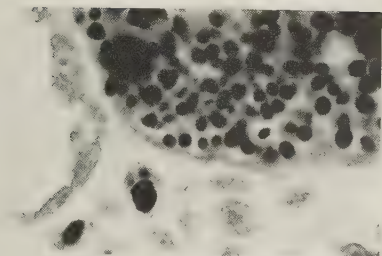


FIG. 1

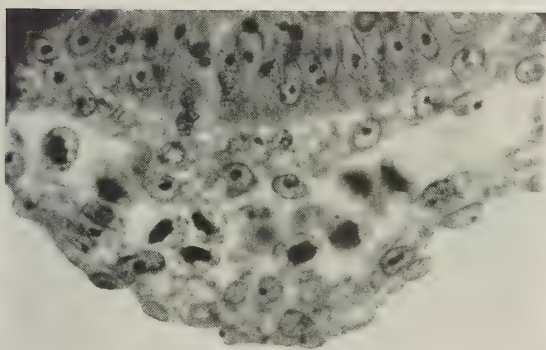


FIG. 2

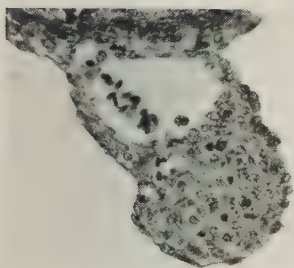


FIG. 3

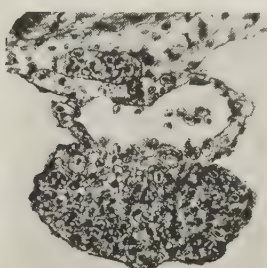


FIG. 4

EXPLANATION OF PLATE LXIV

- FIG. 1. Photomicrograph of the reticulum of the pulp prepared from the residue of spleen-blood serum smears
- FIG. 2. Photomicrograph showing a venule with its stomata. This reveals the manner in which free communication is established between the open sinuses of the pulp and the venous trunks. Taken from half-grown fish (24 cm.)
- FIG. 3. Photomicrograph of a section through an arteriole and three of its ellipsoids. Taken from the adult spleen. Note the disintegrating erythrocyte in the upper ellipsoid and the open communication between the lumen of the lower ellipsoid with the sinuses of the pulp

PLATE LXIV

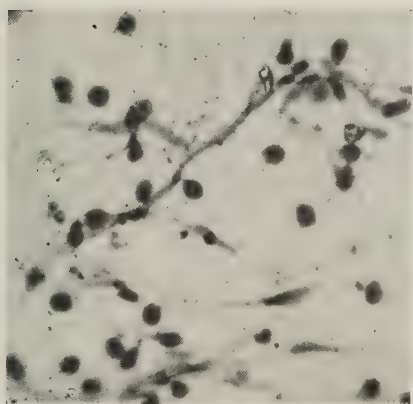


FIG. 1

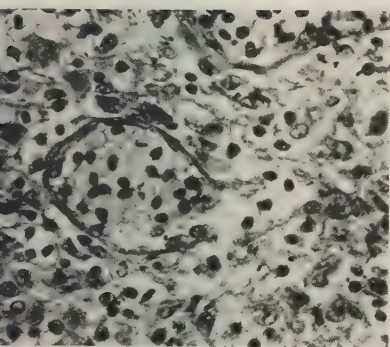


FIG. 2

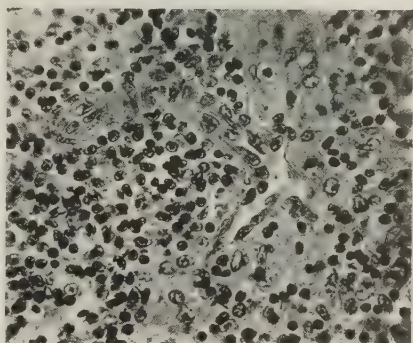


FIG. 3

PRODUCTIVITY OF THE PROFUNDAL BENTHIC ZONE IN LAKE MICHIGAN *

FRANK E. EGGLETON

INTRODUCTION

ONE of the most important, interesting, and difficult fields in American limnology lies in the study of the Great Lakes. It is important from both the theoretical and the applied sides of the subject. It is interesting from each of these aspects and because of the unique nature of the lakes. It is difficult because of the size and the depth of the lakes and the consequent requirements of time and equipment. The opportunity to make this study of Lake Michigan bottom fauna, generously presented to the writer by Dr. John Van Oosten, aquatic biologist in charge of Great Lakes Fisheries Investigations of the United States Bureau of Fisheries, is accordingly deeply appreciated.

Methods, equipment, plans, and the circumstances surrounding the inception of this investigation have been described in a previous paper (Eggletton, 1936) and need not be repeated here. For the sake of proper orientation, however, brief mention needs to be made of the location and the distribution of the samples. In 1931, 75 samples were taken from 49 different depths, ranging from 40 to 244 meters. They were collected between May 11 and November 2 at 49 different stations, distributed generally throughout the southern and the central regions of the lake. The 1932 season began earlier and ended earlier. Ninety-two samples were collected between April 19 and September 12, from 58 different depths, and at 79 different stations. In contrast to 1931, the samples were all collected from the northern end of the open lake and in Green Bay. The depths ranged from 24 to 246 meters. During the two years a total of 167 deep-

* Published with the permission of the United States Commissioner of Fisheries. Contribution from the Department of Zoology, University of Michigan.

water bottom samples were gathered. The majority were drawn from depths between 20 and 150 meters; in fact, only a scattered few were taken below the greater depth.

ORGANISMS COLLECTED

Although but very few of the 1932 samples had been sorted at the time the first report was written, the list of animals present in any considerable numbers has not been extended, even by so much as one form, now that all samples from both years have been studied. This benthic population is dominated in a striking manner by three groups: *Pontoporeia*, Tubificidae, and Sphaeriidae, named in order of decreasing abundance. Of these three, *Pontoporeia* outnumbers all others combined, totaling slightly more than 68 per cent of the entire 1931 population and approximately 62.5 per cent of the animals found in the 1932 samples. This means that one form comprises 65 per cent of the entire macroscopic benthic fauna of Lake Michigan, below the 24-meter contour. Likewise, these three most numerous groups compose an aggregate of approximately 94 per cent of the whole bottom population, and all others combined amount to only 6 per cent of the total (Tables I-IV).

Specimens of *Pontoporeia hoyi* occurred in every sample taken in 1931, except one from 163 meters; and in that sample no animals whatever were found. However, a very large variation was evident from sample to sample, often even when they came from the same or approximate depths. The largest number of these amphipods was encountered in a collection from Station 22E, at a depth of 40 meters. This sample was taken on August 17, 1931. On a basis of that one record the *Pontoporeia* population at that point reached a density of 8,420 individuals per square meter. The most sparse population of this animal was found at depths of 146 and 240 meters. At each of these depths there were but 15 individuals per square meter.

Because *Pontoporeia* so clearly dominated the benthic fauna, curves indicating their depth distribution have been selected for presentation here. Figure 17 depicts the distribution of these animals over the lake floor as it existed in 1931 and 1932. The data from which the curves are plotted (Tables III-IV) represent averages of all samples taken within successive 10-meter intervals.

Two facts must be kept in mind when we study these graphs:

(1) the points on the curves are averages and, therefore, more reliable than individual sample records would be; and (2) the regions of the lake from which the samples were drawn were entirely different in the two years, except in the instance of some of the deepest records. When these facts are remembered, the most remarkable thing about the two curves is their similarities rather than any differences which they exhibit. Below the 50-60-meter stratum — the datum for this region is plotted at 55 meters on the graph — the two curves follow each other with surprising proximity. And even though the magnitude diverges widely above that level, the form of the two lines remains essentially the same.

Aside from the three groups, previously mentioned, which make up so large a part of the whole benthic population, certain other forms inhabit the bottom mud beneath the deeper waters of Lake Michigan. A few of these are widely distributed over the lake floor, although nowhere abundant. All these various organisms, which occur in the profundal benthic habitat either only occasionally or as sparse and widely scattered components of the general bottom fauna, have been regarded as one heterogeneous group in the compilation of the data. This miscellaneous division of the fauna has been assigned the collective name, "All others" (Tables I-II). Within this group the animals probably most consistently present are the nematodes.

DEPTH DISTRIBUTION

Although the samples were widely distributed as regards depth during each season, they were also widely scattered geographically and in no instance were they taken in a definite series from deep to shallow water. Hence, while it is possible to arrange the data in a continuous series according to depth, the details of the depth distribution of this benthic fauna would be more evident if the samples could have been differently distributed. However, by arranging the data according to strata and determining the average number of animals per square meter within those belts of the lake bottom (Tables III-IV) it is possible to make the data take significant form.

Both in 1931 and in 1932 the benthic fauna, regarded as a unit, was very much more abundant above 150 meters than below that depth (Figs. 16-17). Though it is true that there was a much

greater abundance of the animals above the 50-meter level in 1931 than there was in 1932, the difference was purely one of magnitude

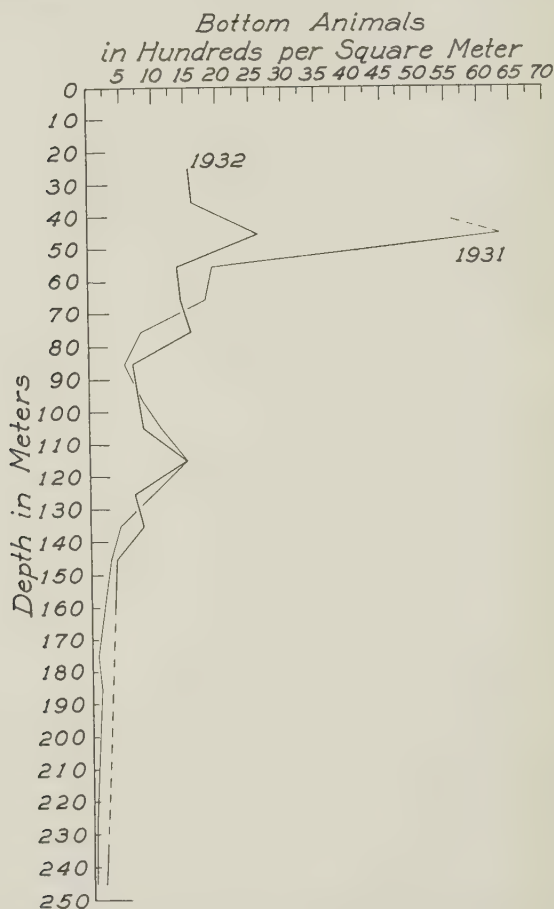


FIG. 16. Depth distribution of benthic animals in Lake Michigan, 1931 and 1932. Averages of all macroscopic benthic animals for each 10-meter stratum

and may very possibly have been due to the fact that the samples from the shallower depths for the two years came from widely separated and ecologically different regions of the lake.

Concentration Zone

Each year a pronounced concentration zone was present between 35 and 50 meters, with its peak close to the 42-meter level in both

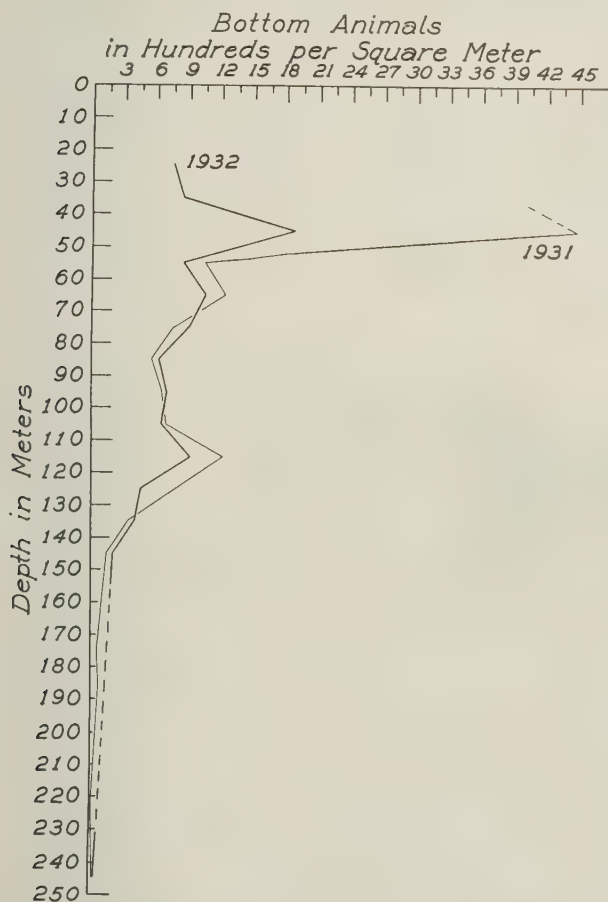


FIG. 17. Depth distribution of *Pontoporeia hoyi*, Lake Michigan, 1931 and 1932.
Average number of animals per square meter for each 10-meter stratum

seasons. Likewise another, but less pronounced, concentration zone is indicated for both years between the depths of 100 and 140 meters,

with its highest point at approximately 115 meters (Figs. 16-18). These regions of greater abundance of the benthic animals are just as evident in the distribution of *Pontoporeia* alone (Fig. 17) as in that of the whole bottom population.

Adamstone (1924, p. 53) has published data relative to the distribution of these amphipods in Lake Nipigon, and for comparison a curve derived from one given by that author is included here (Fig. 18). In this same figure the average number of *Pontoporeia* per square meter for all the Lake Michigan samples, 1931 and 1932 combined, are plotted in curve *M*. Adamstone's data have merely been converted to the present units from those used in his paper. It should be pointed out that the Nipigon curve has been "smoothed," following the original, while the Lake Michigan data are actual averages.

SEASONAL DISTRIBUTION

It is now well known that at least in the smaller, inland lakes of the temperate zone a well-marked seasonal variation characterizes the benthic fauna. In Douglas Lake the writer (Eggleton, 1931) found this seasonal variation to be both qualitative and quantitative in nature. Often this change has been found to be of considerable magnitude from one year to the next. In order to have a reasonably accurate understanding of the normal cycle of events in any lacustrine fauna, records for several consecutive years and covering approximately the same region of the lake need to be at hand. Too much must not be expected, therefore, from the data available for Lake Michigan. True it is that the records are for a considerable portion of each of two consecutive years, but it is likewise true that the samples were widely scattered and not taken in series.

In 1931, when field work began early in May, the bottom animals in the deeper regions of the lake were not particularly abundant. During June a further decline in the average population took place. In July, however, a marked increase became evident, and the maximum of the season was reached in August. The data are arranged by months in Table VI, but when assembled by weeks the same general tendencies are evident, and it is plainly seen that, at least for that one season and in the sections of the lake sampled, a steady increase was in progress, which in practically all instances attained its maximum during the third week of August. Interesting and

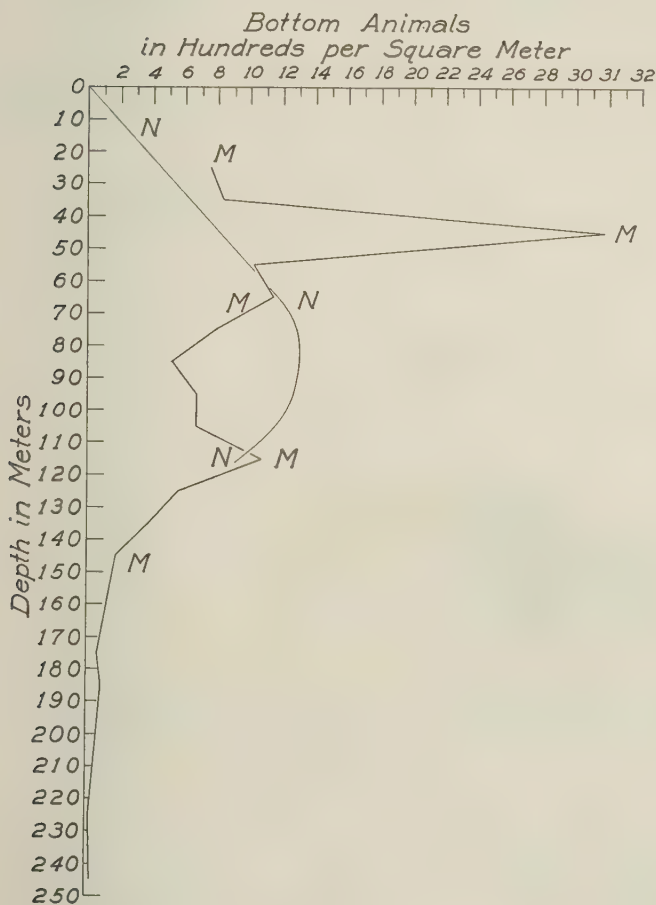


FIG. 18. Depth distribution of *Pontoporeia hoyi* in Lake Michigan (M) and in Lake Nipigon (N). Lake Michigan data indicate average number of animals per square meter within each 10-meter stratum for all samples (1931 and 1932); Lake Nipigon data (from Adamstone, 1924) indicate average number of animals per square meter within each 30-foot stratum for three summers

significant is the fact that, whether the whole population of the lake floor, or *Pontoporeia*, or Tubificidae alone are considered, the result is essentially the same (Fig. 19).

Field work for the season of 1932 began in April, a month earlier than in the year before, but it also came to a close much earlier in

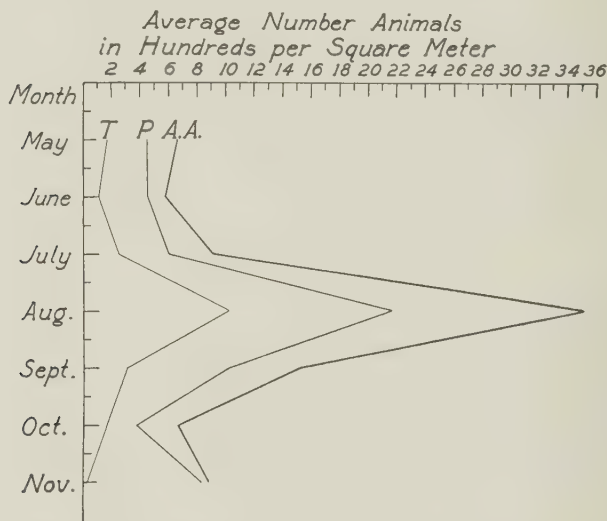


FIG. 19. Seasonal distribution of benthic fauna, Lake Michigan, 1931. Average number of animals in hundreds per square meter for all stations, all depths, and all days within the given months. T, Tubificidae; P, *Pontoporeia*; A.A., all animals

the autumn. The whole field season was, therefore, more than one month shorter (Table VII). Moreover, the work of 1932 was different from that of the preceding year in that, whereas the 1931 samples had all been taken in the open waters of the lake proper and in the southern and central portions, the spring and early summer samples of 1932 came from the relatively more shallow waters of Green Bay and from the northern end of the lake. It seems doubtful, however, whether even these considerable differences could be expected to account for the startling dissimilarities which existed between the seasonal variations of the two years. A moment's comparison of Figure 19 with Figure 20 will suffice to demonstrate that the quan-

titative seasonal variations were greatly different in the two periods. Indeed, the two years seem to have been very nearly opposite in their seasonal abundance of the benthic animals, and differences in sampling do not appear to offer a satisfactory explanation. It seems probable that the natural tendency to vary from year to year, in-

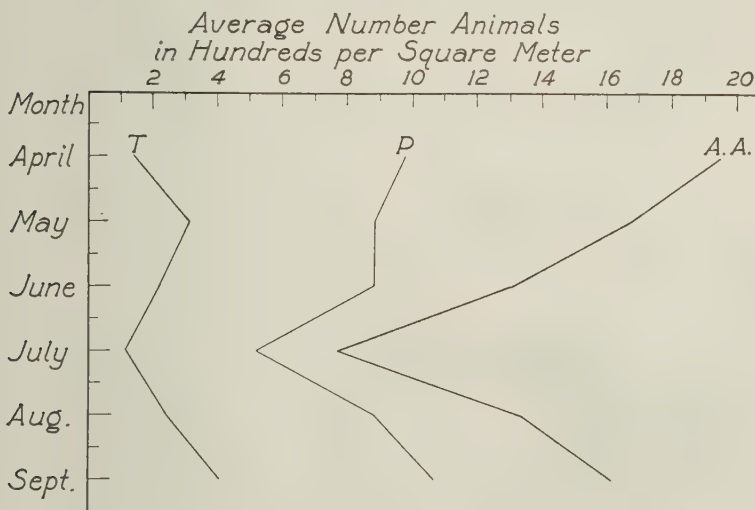


FIG. 20. Seasonal distribution of benthic fauna, Lake Michigan, 1932. Average number of animals in hundreds per square meter for all stations, all depths, and all days within the given months. T, Tubificidae; P, *Pontoporeia*; A.A., all animals

herent in such a biological association, is a more plausible explanation of the observed facts. This hypothesis is strengthened when the 1932 data for the open lake (Table VIII) and those for Green Bay (Table IX) are tabulated separately. It is evident that in both situations the benthic fauna reached a summer minimum in 1932 at almost the same period wherein it had attained its maximum during the preceding summer. It may be possible, of course, that the very considerable increase during August and September, 1932, may have been the summer maximum merely appearing a month later than it did in 1931. In the absence of any data for the rest of the autumn, however, such pure speculation does not carry very strong convic-

tion. It should be pointed out that, in attempting to discover whether or not the data indicated any seasonal variation, certain temporary tabulations of bottom populations were made in which all the records for each separate station were arranged together in chronological order. When so placed the 1931 data showed clearly a general tendency for the population to increase up to the third week of August and thereafter to decline irregularly. No consistent results could be obtained with the 1932 record, largely, it was felt, because there were no instances in which more than two or three samples came from the same station during that year.

PRODUCTIVITY AND CHARACTERISTICS OF THE FAUNA

The period of maximum abundance for the deep-water bottom fauna in many small inland lakes is known to be midwinter. At that time the population of the lake floor is often very dense. Juday (1922) found a maximum of more than 33,000 individuals per square meter in Lake Mendota, and the writer (1931) found a maximum midwinter population in Third Sister Lake in excess of 71,000 animals per square meter. Each of these maxima was dominated by a single form, *Corethra* larvae.

In the Lake Michigan samples which form the basis of this study not one *Corethra* larva has been found. Their place as a dominant form, however, has been taken by the amphipod *Pontoporeia*. The maximum density of population discovered in this study was 10,200 individuals per square meter. This occurred at a depth of 40 meters, on August 17, 1931; and of this population 8,420 were *Pontoporeia*. Considering both years, slightly less than 50 per cent of all samples were from regions of the lake floor on which the total number of all macroscopic animals exceeded 1,000 per square meter.

In addition to the Amphipoda, Tubificidae and Sphaeriidae were also common components of the fauna. Among the Sphaeriidae, however, practically all the individuals which were collected alive belonged to the genus *Pisidium*; only a few specimens of *Sphaerium* were found. The depth distribution of these small bivalves is very irregular, although they occurred at various depths between 52 and 119 meters in 1931 and between 24 and 144 meters in 1932. They were absent, however, from many of the samples between these depths.

As might be expected from the large percentage of *Pontoporeia* in this fauna, the curves for the total macroscopic population resemble

considerably those for the Amphipoda alone. Figure 16 indicates that what was said concerning the similarities of the *Pontoporeia* graphs for the two years could quite as well be extended to include the whole benthic fauna. It is of interest to note that the distribution of the Tubificidae is very much like that of the Amphipoda. Usually a large number of one was accompanied by a dense population of the other. However, several instances exist in which the Tubificidae were absent from a sample, which is in sharp contrast to the all but universal presence of *Pontoporeia*.

A third report, to be published later, on this, the first extensive quantitative study of the profundal benthic fauna in any of the five Great Lakes is now in preparation. In it such topics as reproduction, life-history observations, comparisons with other studies, relation to physicochemical factors, food and predator relationships, and factors limiting distribution are considered.

SUMMARY

1. This report, the second of a series dealing with an extensive quantitative study of the profundal benthic fauna of Lake Michigan, lists the major groups of animals present in this fauna and discusses their abundance, depth distribution, seasonal variation, and general ecology.

2. The study is based on a total of 167 samples collected during the spring, summer, and autumn months of 1931 and 1932 at 128 different stations widely scattered throughout the open lake and in Green Bay. The depths from which the samples were drawn ranged from 24 to 246 meters.

3. The benthic population beneath the deeper waters of Lake Michigan is dominated by three groups: *Pontoporeia*, Tubificidae, and Sphaeriidae, named in order of decreasing abundance. These three groups comprise approximately 94 per cent of the entire benthic fauna, and all others combined amount to but 6 per cent. Of these three most abundant forms, *Pontoporeia* outnumbers all other organisms combined, totaling slightly more than 65 per cent of the whole population.

4. A pronounced *concentration zone* existed between 35 and 50 meters, with its peak close to the 42-meter level in both years. Likewise, a smaller concentration zone was present both years between the depths of 100 and 140 meters.

5. Considered as a unit, the bottom fauna was very much more abundant above the 150-meter contour than below that mark.

6. The 1931 collections indicated a strongly developed midsummer maximum density of population in late August. There was a pronounced increase in number of individuals per unit area up to that period, followed by a clearly marked decline during the autumn months. The 1932 collections, in sharp contrast, demonstrated a decrease in density of population from June through July to a midsummer minimum in the latter month, followed by a large and rapid increase, which continued to the end of the sampling season in late September.

UNIVERSITY OF MICHIGAN

LITERATURE CITED

- ADAMSTONE, F. B. 1924. The Distribution and Economic Importance of the Bottom Fauna of Lake Nipigon with an Appendix on the Bottom Fauna of Lake Ontario. Univ. Toronto Stud., Biol. Series, 25: 33-100; Publ. Ont. Fish. Res. Lab., 24.
- EGGLETON, FRANK E. 1936. The Deep-Water Bottom Fauna of Lake Michigan. Pap. Mich. Acad. Sci., Arts and Letters, 21 (1935): 599-612.
- 1931. A Limnological Study of the Profundal Bottom Fauna of Certain Fresh-Water Lakes. Ecol. Mon., 1 (3): 231-331.
- JUDAY, C. 1922. Quantitative Studies of the Bottom Fauna in the Deeper Waters of Lake Mendota. Trans. Wis. Acad. Sci., Arts and Letters, 20: 461-493.

TABLE I

DEPTH DISTRIBUTION OF BOTTOM ANIMALS
LAKE MICHIGAN, 1931

Depth in meters	Number of samples	Stations	Number of animals per square meter				
			Ponto- poreia	Pisidium	Tubifi- cidae	All others	Totals
40	1	22E	8420	0	1280	500	10200
44	1	22E	7020	0	3680	740	11440
45	1	22E	1200	0	550	35	1785
47	1 (4)	32E	1200	0	740	0	1940
52	2	7E	720	50	1170	0	1940
		26E	3070	370	2030	65	5535
53	1	26E	1710	380	1170	55	3315
54	1	18E	120	0	1200	0	1320
55	1	5E	210	145	180	0	535
56	2	12E	910	0	130	30	1070
		12E	960	30	130	0	1120
57	2	18W	410	35	155	15	615
		18E	90	120	290	35	535
58	1	32E	1580	250	830	15	2675
59	1 (11)	32E	1660	15	530	30	2235
62	1	9W	240	0	220	0	460
63	3	9W	480	55	70	0	605
		5W	300	15	265	15	595
		40W	3170	100	530	80	3880
68	2 (6)	38E	2510	190	1190	60	3950
		49W	670	0	460	15	1145
70	1	30W	560	220	0	180	960
75	1	49E	820	0	30	30	880
77	2 (4)	15W	865	15	0	0	875
		15E	475	0	0	15	490
83	2	25E	580	0	95	30	705
		29E	750	70	90	70	980
84	2	13W	210	0	35	15	260
		45E	1360	0	130	15	1505
87	5	14E	155	55	15	0	225
		14E	560	55	55	0	670
		13E	240	0	850	0	1090
		25E	35	0	0	0	35
		25W	110	0	65	15	190
88	1 (10)	13E	90	0	30	0	120
90	1	23 mid.	660	0	290	15	965
91	1	17E	1100	160	1620	300	3180
95	3	14W	145	0	0	0	145
		14W	70	15	0	0	85
		14W	340	0	220	0	560
96	1	8E	2560	15	270	0	2845
97	3	4E	55	0	0	0	55
		21W	105	0	0	0	105
		21E	190	0	0	0	190
98	3 (12)	8E	880	0	15	0	895
		21W	210	0	0	15	225
		17E	1460	160	1090	380	3090

TABLE I (Concluded)

Depth in meters	Number of samples	Stations	Number of animals per square meter				
			Ponto- poreia	Pisidium	Tubifi- cidae	All others	Totals
100	1	8E	855	0	0	0	855
101	1	17E	740	0	320	15	1075
103	1	31W	30	0	0	160	190
106	1	44W	1150	0	95	140	1385
107	4	37W	1060	65	820	0	1945
		41W	95	15	0	0	110
		44W	690	0	190	15	895
		44W	340	0	80	130	550
108	2	41E	2050	250	1940	430	4670
		17E	320	0	95	110	525
109	2 (12)	17E	475	0	35	0	510
		31E	440	0	0	0	440
116	2	20W	590	0	35	495	1120
		17W	1470	0	30	50	1550
119	1 (3)	23W	1570	15	220	15	1820
133	1	46E	350	0	35	330	715
135	1	10E	820	0	50	15	885
138	1	20E	120	0	55	0	175
139	1 (4)	33E	120	0	15	0	135
144	1	17W	430	0	30	0	460
145	1	47W	110	0	65	400	575
146	2 (4)	33E	35	0	70	35	140
		38E	15	0	30	30	75
163	1 (1)	35E *					
172	1 (1)	47E	70	0	35	15	120
189	1 (1)	32W	90	0	70	0	160
220	1 (1)	A	20	0	0	50	70
244	1 (1)	C	35	0	15	0	50

* No organisms found.

TABLE II

DEPTH DISTRIBUTION OF BOTTOM ANIMALS
LAKE MICHIGAN, 1932

Depth in meters	Number of samples	Stations	Number of animals per square meter				
			Ponto- poreia	Pisidium	Tubifi- cidae	All others	Totals
24	1	12SE	600	35	375	330	1340
25	1	9NE	1300	90	60	600	2050
	1	12NW	115	75	35	1100	1325
	1	15NE	120	0	110	90	320
26	1	11NW	590	120	145	420	1275
27	1	14SW	2500	230	145	850	3725
28	1	4SE	375	15	120	920	1430
	1	5NE	675	115	270	600	1660
	1	19W	1720	75	600	390	2785
29	1	19E	130	0	15	80	225
	1 (11)	8NW	55	90	90	640	875
30	1	1NW	410	35	120	1820	2385
31	1	3NW	120	0	15	120	255
	1	2NW	2585	110	0	210	2905
	1	10NE	245	90	55	175	565
	1	10NE	180	20	80	60	340
	1	21S	2120	165	2290	620	5195
	1	22NW	230	145	90	265	730
32	2	23SW	115	95	15	0	225
	1	6NE	110	15	175	55	355
	1	6SW	3765	1145	420	1610	6940
	1	6SW	375	125	115	40	655
	1	18SE	610	110	155	1120	1995
	1	18SE	300	160	160	720	1340
	1	20N	230	15	0	75	320
	2	55E	50	115	195	205	565
34	1	16S	2410	90	35	55	2590
35	1	13NE	550	145	115	90	900
	1	17N	860	115	15	155	1145
	2 (22)	23SW	510	255	135	100	1000
41	1	24W	2660	440	1300	210	4610
44	1	24E	2000	1440	380	470	4290
45	1	25NW	1650	280	55	35	2020
46	1	25SE	3170	530	80	80	3860
	1	25SE	1610	45	150	125	1930
48	1	55W	1410	35	75	15	1535
	1	57S	1160	30	130	30	1350
49	1 (8)	41NE	1310	0	90	0	1400
55	1	60	380	115	75	115	685
58	1	41NE	1275	225	145	15	1660
59	1 (3)	34N	1325	165	215	55	1760
60	1	53W	120	0	155	35	310
62	1	29W	870	55	230	15	1170
65	1	50E	1360	590	425	0	2375
	1	54W	3000	250	0	0	3250
66	1	35E	90	35	15	70	210
68	1 (6)	27E	850	0	335	60	1245

TABLE II (Concluded)

Depth in meters	Number of samples	Stations	Number of animals per square meter				
			Ponto- poreia	Pisidium	Tubifi- cidae	All others	Totals
70	1	52W	810	115	225	20	1170
75	1	32SE	1150	55	410	145	1760
	1	45W	910	55	120	15	1100
76	1	46S	1380	320	145	15	1860
77	1	57N	825	600	1525	0	2950
78	1	52E	980	540	195	35	1750
79	1 (7)	42SE	245	0	70	90	405
82	1	33N	1440	120	420	120	2100
83	1	33N	770	15	55	75	915
86	1	67NW	120	15	245	0	380
87	1 (4)	67NW	175	15	110	55	355
91	1	27W	725	0	320	15	1060
93	1	38SE	290	0	35	550	875
94	1	27W	1125	0	330	35	1490
96	1	31W	175	15	110	0	300
	1	32W	595	0	110	55	760
97	1 (6)	28W	1220	50	110	160	1540
100	1	43SE	605	0	245	110	960
101	1	30E	450	15	50	15	530
	1	30E	320	0	230	15	565
102	1	67SE	560	0	30	65	655
105	1	63SW	370	30	190	0	590
106	1	32NW	1220	15	180	15	1430
	1	55S	1570	0	190	160	1920
107	1 (8)	37NW	55	0	70	0	125
114	1	49E	130	0	180	15	325
	1	51NW	1250	30	80	320	1680
118	1	36SE	130	0	15	15	160
	1	53E	155	0	70	120	345
	1	59NW	785	15	135	15	950
	1	66NW	1740	180	1410	530	3860
	1	59SE	2400	30	435	85	2950
119	1	C	510	0	1230	65	1805
	1	48E	600	15	355	0	970
	1 (10)	66NW	1460	0	510	15	1985
123	1	36NW	100	0	15	15	130
124	1	26E	580	15	55	110	760
128	1 (3)	35W	1000	35	180	35	1250
130	1	35W	190	50	350	95	685
132	1	36SE	70	0	35	0	105
139	1	D	1040	50	530	95	1715
	1 (4)	35W	320	130	290	95	835
144	1 (1)	54E	210	0	120	90	420
240	1	B	15	0	15	200	230
246	1 (2)	A	70	0	15	90	175

TABLE III

DEPTH DISTRIBUTION OF BOTTOM ANIMALS BY STRATA
LAKE MICHIGAN, 1931

Strata in meters	Total number samples	Number different stations	Average number of animals per square meter within strata				
			Ponto- poreia	Pisidium	Tubifi- cidae	All others	All animals
40- 49	4	2	4460	0	1565	320	6345
50- 59	11	7	1040	130	710	25	1905
60- 69	6	5	1230	60	455	30	1775
70- 79	4	4	680	60	10	60	810
80- 89	10	7	410	20	140	15	585
90- 99	12	7	650	30	300	60	1040
100-109	12	8	690	30	300	85	1105
110-119	3	3	1210	5	95	190	1500
130-139	4	4	350	0	40	90	480
140-149	4	4	150	0	50	120	320
170-179	1	1	70	0	35	15	120
180-189	1	1	90	0	70	0	160
220-229	1	1	20	0	0	50	70
240-249	1	1	35	0	15	0	50

TABLE IV

DEPTH DISTRIBUTION OF BOTTOM ANIMALS BY STRATA
LAKE MICHIGAN, 1932

Strata in meters	Total number samples	Number different stations	Average number of animals per square meter within strata				
			Ponto- poreia	Pisidium	Tubifi- cidae	All others	All animals
20- 29	11	11	750	80	180	545	1555
30- 39	22	16	830	155	220	395	1600
40- 49	8	7	1870	350	280	120	2620
50- 59	3	3	995	170	145	65	1375
60- 69	6	6	1050	155	195	30	1430
70- 79	7	7	900	240	385	45	1570
80- 89	4	2	625	40	210	65	940
90- 99	6	5	690	10	170	135	1005
100-109	8	7	645	10	150	50	855
110-119	10	9	915	30	440	120	1505
120-129	3	3	560	15	85	55	715
130-139	4	3	405	60	300	70	835
140-149	1	1	210	0	120	90	420
240-249	2	2	40	0	15	145	200

TABLE V
 DEPTH DISTRIBUTION OF BOTTOM ANIMALS BY STRATA
 LAKE MICHIGAN, 1931 AND 1932
 Averages of all samples for both years

Strata in meters	Total number samples	Number different stations	Average number of animals per square meter within strata				
			Ponto- poreia	Pisidium	Tubifi- cidae	All others	All animals
20- 29	11	11	750	80	180	545	1555
30- 39	22	16	830	155	220	395	1600
40- 49	12	9	3165	175	925	220	4485
50- 59	14	10	1020	150	430	45	1640
60- 69	12	11	1140	110	325	30	1605
70- 79	11	11	790	150	200	50	1190
80- 89	14	9	520	30	175	40	765
90- 99	18	12	670	20	235	95	1025
100-109	20	15	670	20	225	65	980
110-119	13	12	1065	15	270	150	1505
120-129	3	3	560	15	85	55	715
130-139	8	7	380	30	170	80	660
140-149	5	5	180	0	85	105	370
170-179	1	1	70	0	35	15	120
180-189	1	1	90	0	70	0	160
220-229	1	1	20	1	0	50	70
240-249	3	3	35	0	15	70	125

TABLE VI
 SEASONAL DISTRIBUTION OF BENTHIC ANIMALS
 LAKE MICHIGAN, 1931

Months	Average number of animals per square meter for all sta- tions, all depths, and all days within the given months		
	Pontoporeia	Tubificidae	All animals
May	450	170	655
June	450	110	580
July	605	255	910
August	2165	1025	3505
September	1025	310	1510
October	375	165	660
November	820	30	880

TABLE VII

SEASONAL DISTRIBUTION OF BENTHIC ANIMALS

LAKE MICHIGAN, 1932

(Green Bay and open lake)

Months	Average number of animals per square meter for all stations, all depths, and all days within the given months		
	Pontoporeia	Tubificidae	All animals
April	975	140	1950
May	880	310	1670
June	880	220	1305
July	520	135	770
August	885	240	1340
September	1070	405	1620

TABLE VIII

SEASONAL DISTRIBUTION OF BENTHIC ANIMALS

LAKE MICHIGAN, 1932

(Open lake)

Months	Average number of animals per square meter for all stations, all depths, and all days within the given months		
	Pontoporeia	Tubificidae	All animals
May	410	120	1005
June	675	240	1015
July	520	135	770
August	885	240	1340
September	1070	405	1620

TABLE IX

SEASONAL DISTRIBUTION OF BENTHIC ANIMALS

LAKE MICHIGAN, 1932

(Green Bay)

Months	Average number of animals per square meter for all stations, all depths, and all days within the given months		
	Pontoporeia	Tubificidae	All animals
April	975	140	1950
May	935	330	1750
June	1710	135	2465

SOME CHARACTERISTICS OF A POPULATION OF STUNTED PERCH *

R. WILLIAM ESCHMEYER

AN EXAMINATION of the pothole lakes in the Pigeon River State Forest, Otsego and Cheboygan counties, made by the Institute for Fisheries Research in 1932 showed that several of these small lakes contained an abundance of yellow perch (*Perca flavescens*); several others contained only minnows, or minnows and brook trout where the latter had been planted. In 1933 most of these lakes were stocked with trout. Subsequent study indicated that the survival and growth of the trout were good in lakes which did not contain perch, but were poor in those in which perch were abundant. It was observed that, in general, the perch were in poor condition; most of those taken were small and thin. The lakes which contain perch are fished very little, but those with only trout (and minnows) provide excellent fishing.

It was decided, in 1934, to make an effort to remove the fish from one of these perch lakes after poisoning and to stock it later with trout. South Twin Lake, T. 32 N., R. 1 W., Section 10, was selected for the experiment. This lake, according to the Institute's 1932 survey, has an area of 4.3 acres (1.74 hectares) and a maximum depth of 12.7 meters. The outline is roughly circular, and the basin is bowl-shaped, with limited shoal area. It was determined also that in summer the water is definitely stratified, with the thermocline at a depth of from 4 to 7 meters. The bottom soil at the margin is sand, in deeper water it is organic (pulpy peat). The water is relatively clear (Secchi disk reading 7.5 meters) and is alkaline (surface pH 8.7). This small, land-locked lake has high, steep, sandy banks, and the drainage area is very small.

Gill nets of seven mesh sizes varying from $1\frac{1}{4}$ to 4 inches, stretched measure, were fished in this lake several weeks before the poisoning,

* Contribution from the Institute for Fisheries Research of the Department of Conservation and the University of Michigan.

and five sticks of dynamite were discharged at the same time. The perch obtained by these two methods were placed in one lot (Lot 4 of this study).

On the morning of September 20, 1934, an Institute party consisting of Milton B. Trautman and the writer distributed about 48 pounds of powdered derris root (5 per cent rotenone content) over the surface of the lake. Most of the poison was spread by pouring it in the wake of an outboard motor. The remainder was broadcast by hand. About eight hours after the poison had been distributed 100 sticks of 40 per cent dynamite were discharged in deep water (in three lots of approximately 25, 25, and 50 sticks) in order to assure a thorough circulation of the poison throughout the lake.

The poison had killed a considerable number of fish before the dynamite was discharged. Many of these perch were collected and are included here as Lot 1. Another lot (Lot 2) was collected on the same day, but after the dynamiting. Lot 3 was collected on the following day. Most of the fish which floated, or which sank in shallow water, were recovered. To check the effectiveness of the poison and the dynamite, a gill net with the same mesh sizes as the one previously used was set in the lake overnight several weeks later, but it took no fish. A live perch was seen, however, at the time the net was lifted. Not all the perch were killed and not all of those killed were recovered.

The perch in all four lots were preserved in 10 per cent formalin and were later transferred to 70 per cent alcohol. All studies of them were made from preserved specimens. In addition to the perch a few trout were taken by netting and two were recovered after poisoning. No other species were taken or are known to have been present. Data concerning the trout are not included in this study.

The purpose of this paper is to describe some of the characteristics of this population of stunted perch, based on the collection obtained by the several methods indicated above. Unfortunately, the entire population could not be collected for study. The fish came to the surface when dying, and wave action tended to wash the dead ones toward the shore region, where they continued to float or sank in shallow water. Although a precise estimate of the percentage of the total population recovered is not possible, it is believed that the percentage is relatively large (well over 50 per cent).

TOTAL POPULATION

The four lots included a total of 3,615 perch. In addition, 503 perch were counted lying on the bottom after the last lot had been recovered. A total of 4,118 fish are, therefore, definitely known to have been present in the lake. This number represents 955 perch per acre. Since not all the fish were seen or recovered, the total population was unquestionably well in excess of 1,000 fish per acre.

The 3,615 perch had a total weight of 109.3 pounds (49,591 grams). This represents a weight of 25.4 pounds per acre. If the 503 perch which were seen but not collected were of the same average weight, they represented a total of 15.2 pounds, increasing the total weight per acre to about 29 pounds. The weight of the entire population was most probably well in excess of 30 pounds per acre.

SIZE AND AGE DISTRIBUTION

Weight, length, and age were determined for all specimens. Both standard and total lengths were recorded to the nearest millimeter. The fish were weighed on a Welch balance which was calibrated to tenths of grams. The small fish were weighed in groups of 2 to 90 fish per group, but all fish older than the II group were weighed individually. The length distribution, irrespective of age or sex, is shown in Table I, where the fish are grouped by 10-mm. intervals. The pronounced mode at 80-89 mm. suggests that most of the fish probably belonged to one age group. Another mode at 110-119 mm. suggests the presence of another age group; however, this second mode actually consists of fish of several age groups.

Ages were determined for all the 3,615 fish by examination of the scales by means of a binocular microscope. The annuli were located easily in the young fish (I and II groups), but were difficult to find in the scales from some of the older fish, especially in those from individuals in poor condition, since many of these emaciated individuals had apparently partially resorbed portions of their scales (see Pl. LXVI, Fig. 2). On some specimens a large number of scales were examined before the age could be determined with any degree of certainty. Even though the scales were studied carefully, it is possible that the age determinations on some of the older fish were incorrect.

TABLE I

SIZE DISTRIBUTION OF ALL PERCH, SEXES COMBINED,
BY 10-MILLIMETER CLASSES (STANDARD LENGTH)

<i>Size class</i>	<i>Number</i>	<i>Percentage of total</i>
50-59	3	0.1
60-69	0	0.0
70-79	144	4.0
80-89	2270	62.8
90-99	345	9.5
100-109	112	3.1
110-119	357	9.9
120-129	222	6.1
130-139	93	2.5
140-149	32	0.9
150-159	18	0.5
160-169	7	0.2
170-179	3	0.1
180-189	3	0.1
190-199	0	0.0
200-209	0	0.0
210-219	2	0.1
260-269	1	0.0
270-279	1	0.0
280-289	1	0.0
290-299	1	0.0
Total	3615	99.9

The number of perch in each age group is shown in Table II. The ages indicate the number of winter marks (annuli). Since most of the fish were taken in mid-September (20th), the fish were actually almost if not wholly one growing season older than the recorded ages.

Over three fourths (76.7 per cent) of the fish were in one age group (II). There were more fish in the III and IV groups than in the 0 and I groups. The only age group represented by a mode in the length distribution is the II group.

In general, after the second year the females grew more rapidly than the males. In the I group the males were, on the average, longer and heavier than the females. In the II group both sexes were of about equal length and weight, and in all groups older than II the females were decidedly longer and heavier. A few of the female perch reached an exceptionally large size. The single perch in

TABLE II

NUMBER OF FEMALE AND MALE PERCH IN EACH AGE GROUP, AND
AVERAGE LENGTH AND WEIGHT OF FISH IN EACH GROUP

Sex	Age group							
	0	I	II	III	IV	V	VI?	Over VI
Females (1530)								
Lot 1.....	2	27	607	24	66	13	..	2
Lot 2.....	..	..	284	4	31	3	..	..
Lot 3.....	..	..	320	6	31	2	1	..
Lot 4.....	..	1	27	65	13	..	..	1
Total.....	2	28	1238	99	141	18	1	3
Males (2085)								
Lot 1.....	1	45	638	132	11	..	..	..
Lot 2.....	..	3	497	59	32	..	..	..
Lot 3.....	..	10	361	108	42	..	..	..
Lot 4.....	..	13	40	84	9	..	..	..
Total.....	1	71	1536	383	94	..	..	..
Total (both sexes)	3	99	2774	482	235	18	1	3
Percentage of total collection.....	0.1	2.7	76.7	13.3	6.5	0.5	0.0	.1
Average standard length in mm.								
Females.....	44	80.4	87.1	125.0	134.2	169.1	274.0	282.0
Males.....	43	89.0*	84.4	116.0	121.1	.....	.....	.....
Average weight in grams								
Females.....	2.7	7.7	9.6	30.2	35.3	76.5	445.3	443.3
Males.....	2.7	11.3*	9.7	21.7	25.0	.....	.....	.....
Average (approx.) total length in inches								
Females.....	2.1	3.8	4.1	5.9	6.3	7.88	12.49	13.83
Males.....	2.0	4.2	4.0	5.5	5.7	.....	.....	.....
Average weight in ounces								
Females.....	0.09	0.27	0.34	1.07	1.25	2.70	15.73	15.65
Males.....	0.09	0.40	0.37	0.77	0.89	.....	.....	.....

* A number of the males in the I group showed exceptionally rapid growth as compared with the older fish and with other members of the same age group.

the VI? group weighed more than 45 perch in the II group and almost as much as 18 average-sized male perch from the oldest group of males (IV). In his study of perch in three northern Wisconsin lakes Schneberger (1935) found that the females grew much faster than the males in Silver Lake, the lake with the slowest-growing population. This is in accord with data for South Twin Lake perch. In the two Wisconsin lakes (Weber Lake and Nebish Lake) where the fish grew more rapidly the difference in growth rate of the two sexes was much less pronounced.

The dominant group (II) averaged only slightly over four inches in total length, and only a little over a third of an ounce in weight.

Some of the males in the I group grew very rapidly as compared with the other fish of the same age and sex. This rapid growth of a few individuals raised decidedly the average length and weight for this group. Such unusual growth was present also in a few of the perch of the II group, but was not observed in the older fish. Schneberger (1935) noted a similar rapid growth in some of the young fish of the perch of Wisconsin lakes. He stated that "In the younger fish [age groups II and III] cases are found where the annulus is far from the focus, indicating an extremely rapid growth. However, this type is rarely found in the older fish, suggesting that the rapid growers are shorter-lived."

The approximate number of legal-sized fish in the South Twin Lake perch population was calculated. Since all the perch were measured after they were preserved, it is impossible to determine exactly the number of fish of a given length because the amount of shrinkage is not known. However, an approximate correction for shrinkage after preservation was obtained through the application of the shrinkage factor, 1.016, determined by Van Oosten (1929) for the lake herring. The legal length for perch in Michigan is 152.4 mm. (6 inches). This figure divided by the shrinkage factor equals 150 mm. Accordingly, all perch with a length of 150 mm. or more (after preservation) are here considered to be of legal length. The number, age, and average length of all perch 150 mm. or more in length are shown in Table III. The percentage of legal fish in each age group is presented also.

If the allowance for shrinkage was correct, 7 per cent of all the fish collected, or approximately 60 fish per acre, were of legal length. The ratio of legal females to legal males was approximately 4 to 1

TABLE III

NUMBER, AGE, AND SEX OF ALL LEGAL-SIZED PERCH
(With total length of 150 mm. or more when preserved)

Number and percentage of all fish in age groups	Age group											
	II		III		IV		V	VI?	Over VI	Total		
	Male	Female	Male	Female	Male	Female	Female	Female	Female	Male	Female	Both sexes
Number	4	1	31	50	19	126	18	1	3	54	199	253
Percentage ..	0.3	0.1	8.1	50.1	20.2	89.4	100	100	100	2.6	13.0	7.0

(199 to 54). Since some of these fish had very large heads and were in poor condition, and since some were parasitized rather heavily (Pl. LXVI, Fig. 1), the percentage of desirable legal-sized fish in the total population was very small, certainly less than 5 per cent.

For comparison of growth of the South Twin Lake perch with perch from other waters the lengths of this species at different ages

TABLE IV

AVERAGE STANDARD LENGTH IN MILLIMETERS OF PERCH IN VARIOUS AGE GROUPS FROM SEVERAL LAKES (ADAPTED FROM SEVERAL AUTHORS)

Investigator	Lake	Age group				
		I	II	III	IV	V
Eschmeyer	South Twin	87	86	118	129	169
Harkness	Lake Erie	...	144	168	187	217
Hile *	Wawasee (Ind.)	86	129	167	198	220
Jobes †	Lake Erie	161	178	196	213	250
Schneberger ‡	Nebish (Wis.)	124	157	173	209	245
Schneberger §	Weber (Wis.)	...	130	158	174	191
Schneberger ||	Silver (Wis.)	...	109	120	145	173

* Data for 1926, 1927, 1928 combined.

† Data for 1927 and 1928 combined.

‡ Data for 1930, 1931, 1932 combined.

§ Data for 1928, 1930, 1931, 1932 combined.

|| Data for 1928, 1930, 1931 combined.

as determined by Harkness (1922), Hile (1931), Jobes (1933), and Schneberger (1935) are recorded in Table IV. In all these studies the lengths given are measured lengths of fish taken in the summer or the fall. It will be noted that, in general, the perch from South Twin Lake grew much more slowly than those from the other lakes. This slow growth is brought out in a striking manner by comparison with Jobes' data for the Lake Erie perch. In Lake Erie the perch had attained an average size in the II group greater than that of the South Twin Lake perch in the V group.

SEX RATIO

For the entire population the sex ratio was 74 females per 100 males, or approximately a 3 to 4 ratio. The ratios for the different lots were:

Lot 1.....	89 females per 100 males
Lot 2.....	54 females per 100 males
Lot 3.....	69 females per 100 males
Lot 4.....	74 females per 100 males

The ratios vary considerably from one lot to another. Incidentally, Lot 4, the smallest lot, showed a proportion of females to males identical with the proportion of the two sexes for all lots combined. It is possible that the poisoning was selective or that one sex floated more readily than the other after being killed. However, if the poisoning was no more selective than capture by gill nets or other methods used to take fish, the data suggest that apparently random samples of a perch population may lack reliability in respect to the sex ratio. It is possible that, at certain times of the year at least, these fish school in separate sexes.

In this slow-growing population of perch the larger fish tended to be predominantly females. The fish with five or more annuli were all females. In the IV group the females predominated, but in the I, II, and III groups males were decidedly more abundant than females. Apparently the females had a considerably longer life span than the males, a condition which is common among fishes and among many other forms of animal life as well. Geiser (1924) held that females are inherently better fitted than males to survive adverse environmental conditions. Schneberger (1935) found the large fish to be predominantly females in two of the three Wisconsin perch populations examined by him. Three of the four cisco (*Leu-*

cichthys artedi) populations of northern Wisconsin lakes studied by Hile (1936) showed a preponderance of females. Hile stated, further, that "with the exception of the irregular data on Silver Lake the females tend to become relatively more abundant as age increases."

These observations offer strong support to the suggestion that in analyzing a given sample of fish with respect to sex ratio the age composition must be given consideration. Had gill nets been used to obtain the sample in South Twin Lake most of the young fish would not have been captured and females would have been found relatively more abundant. The scarcity of young fish in Schneberger's samples of perch from Wisconsin lakes probably accounts for the disagreement between his data on the sex ratios in the species and those obtained for South Twin Lake. Schneberger found the ratio of females to males to be 100:126 in Nebish Lake, 100:76 in Weber Lake, and 100:71 in Silver Lake. The conclusions were based on 355, 407, and 392 fish respectively. Silver Lake, with the greatest concentration of perch and with the slowest-growing perch, had the largest proportion of females (58 per cent). It is possible that his sex ratios would have been decidedly different had he been able to examine a larger number of young fish. The fact that the perch in South Twin Lake were dominantly young fish (primarily of the II group) certainly had a bearing on the sex ratio found for the fish in that lake and on the disagreement with Schneberger's results.

CONDITION OF PERCH¹

The coefficient of condition, or "index of relative heaviness," was determined for individual fish. The formula $K = \frac{W \times 10^5}{L^3}$ was used, where W = weight in grams and L = standard length in millimeters.

Since the small size of the perch in the age groups 0, I, and II made it impractical to weigh all these individually, the values of K for fish in these age groups are only approximate. The values of K were calculated individually for all older fish. Table V shows the value of K for each age group.

The values of K were identical for the males and the females in the I group. In the II group the males were in slightly better

¹ Discussions of coefficient of condition and length-weight relationship are found in papers by Hile (1936) and others.

TABLE V
AVERAGE VALUE OF *K* FOR PERCH IN EACH AGE GROUP *

Sex	Age group †							Average
	I	II	III	IV	V	VI?	Over VI	
Females . . .	1.49	1.46	1.51	1.42	1.46	2.17	1.97	1.46
Males	1.49	1.51	1.41	1.41	....	....	....	....
Both sexes . .	1.49	1.49	1.43	1.42	1.46	2.17	1.97	1.46

* Number of perch in each group shown in Table II.

† 0 group not included in this table.

condition, but in the groups older than II the condition of the females was better than that of the males. The fish as a whole were in poorest condition in the III and IV groups.

The distributions of the individual values of *K* were determined for each sex in each age group older than II. Without presentation of the extensive tabular material it may be stated that for most groups the distribution is approximately that of a normal curve. In the population as a whole the condition varies over a wide range — from a minimum of less than 1.0 to a maximum of over 2.0. The two extremes for females are shown in Plate LXV.

A comparison of the condition of the South Twin Lake perch with that of perch in other waters as determined by Schneberger and Hile is presented in Table VI. The fish from all the lakes were collected in summer or fall. It will be noted that, with the exception of the Weber Lake II group, the condition of perch from South Twin Lake was poorer than that in the other four lakes. In making comparisons of the *K* values for South Twin Lake perch with those of other populations, it should be remembered that all the Twin Lake perch were weighed after preservation. There is a strong possibility that the Twin Lake perch may have lost weight on preservation and that, consequently, the recorded values found for *K* may be too low. That fish do lose weight on preservation is indicated by the observations of Hile (1936), who found the shrinkage factor for the weight of cisco in one lake (Muskellunge) to be 1.181, and in another lake (Clear), 1.144. Data on the actual shrinkage of perch on preservation are not available.

TABLE VI

VALUE OF K FOR PERCH IN THREE WISCONSIN LAKES AND ONE INDIANA LAKE AS COMPARED WITH VALUE OF K FOR THE PERCH OF SOUTH TWIN LAKE

Investigator	Lake	Age group				
		I	II	III	IV	V
Eschmeyer	South Twin	1.49	1.49	1.43	1.42	1.46
Hile *	Wawasee (Ind.)	1.51	1.63	1.60	1.77	1.70
Schneberger †	Nebish (Wis.)	1.67	1.64	1.63	1.72	1.75
Schneberger †	Weber (Wis.)	1.65	1.44	1.54	1.61	1.65
Schneberger †	Silver (Wis.)	....	1.57	1.60	1.61	1.65

* Data for 1926, 1927, 1928, and 1929 combined.

† Data for 1930, 1931, and 1932 combined.

HEAD LENGTH

Repeated observations of systematists suggest that in normally growing fresh-water fishes the head grows relatively more slowly than the body. In the South Twin Lake perch, however, the

TABLE VII

HEAD LENGTH (B/H)
Extreme head length in standard length

Sex	Age group						
	I	II	III	IV	V	VI?	Over VI
Females							
Number.....	1	28	76	78	18	1	3
B/H.....	3.20	3.09	2.84	2.86	2.96	2.95	3.06
Males							
Number.....	13	42	121	5	....	....	....
B/H.....	3.11	3.10	2.90	2.78	....	....	....

head generally grew more rapidly, in proportion, than the body (Table VII).

The South Twin Lake perch appear to be unusual also in the possession of a head relatively much larger than that ordinarily recorded for the species. Jordan (1929) indicates that in perch the

head length is contained in the body length $3\frac{1}{4}$ times. The head length of the perch in South Twin Lake was obviously much greater than the head length given by Jordan for this species.

Attention should be called to a possible correlation between the coefficient of condition and head length. A comparison of Tables V and VII suggests that, in general, the fish in poor condition have relatively the larger heads in this slow-growing population. The III and IV groups were in poorest condition (Table V); these same two groups had, relatively, the largest heads (Table VII).

Because of the relatively large heads in this slow-growing population it was considered possible that the slow growth itself might be responsible for the large heads. If this were true, the more rapidly growing fish of an age group might be expected to have the smallest heads. However, a study of the head length for 128 specimens of the III group indicates that the head length varies little with differences in growth, although there is a suggestion that the head is larger in the faster-growing fish (130 to 150 mm.). Because of the small number of specimens the averages for some of the intervals lack reliability. The average sizes of heads for fish of different lengths are shown in Table VIII.

TABLE VIII

HEAD LENGTH (B/H) OF PERCH IN VARIOUS SIZE GROUPS

All specimens belong to one age group (III).

<i>Group interval in mm.</i>	<i>Number of specimens</i>	<i>B/H</i>
105-109	6	2.90
110-114	33	2.87
115-119	67	2.86
120-124	25	2.85
125-129	10	2.88
130-134	7	3.11
135-139	2	2.93
140-144	3	2.97

FOOD

No study was made of the abundance of food organisms in the lake, but the stomach contents of a number of fish were examined. The stomachs of a considerable proportion of the larger fish contained perch, most of which were undigested. Very possibly, how-

ever, such a large number of fish may not normally contain perch in their stomachs. It is probable that the smaller perch were incapacitated by the poison before the large fish were affected and were, therefore, easily captured by the large individuals. In spite of the fact that the abundance of young perch in the stomachs of the larger fish was probably much higher than normal, the small perch obviously are an important food item for the large individuals. It is possible that the excellent condition of the larger females (part of the IV group and all older than the IV) is attributable to the presence of the abundant supply of perch (chiefly the II group) small enough to be taken by them.

A stomach analysis of 34 fish of the I group indicated that insect larvae and nymphs and small crustaceans constituted almost the entire food supply. Chironomids and Cladocera were the most common organisms. The insects included also Diptera (other than Chironomidae), Ephemerida, Trichoptera, Coleoptera, and Odonata. The stomachs generally contained relatively little food, but only one of the 34 was completely empty. It was observed, further, that individual stomachs contained either insects or crustaceans; none were found to contain both forms.

Analysis of stomachs of the II group (50 specimens) showed that the food of this group is essentially the same as that of the I group, except that a greater proportion of the stomachs contained crustaceans. The insects included chiefly immature Diptera and Ephemerida. A few Trichoptera were also eaten. The Crustacea were mostly Cladocera.

Stomachs of 40 fish of the III group were examined. The bulk of the food consisted of Diptera larvae and nymphs, with Chironomidae and Corethera predominating. Some small snails and small clams were eaten, along with leeches, algae, Trichoptera, Hemiptera, and Hymenoptera. Six of the stomachs were empty.

The food in the stomachs of 40 fish in the IV group was essentially similar to that of the III group. The most important items were Diptera, with Corethera predominating. Other forms, such as snails, clams, Odonata, Orthoptera, Coleoptera, Ephemerida, Trichoptera, leeches, and crayfish, were taken in very small quantities.

If the population is considered as a whole, it may be stated that at the time the perch were taken Diptera constituted the chief food, with Chironomidae and Corethera apparently supplying the bulk of

it. In general, the stomachs were relatively very small and contained little food. However, only 13 of the 164 stomachs were entirely empty. A scarcity of satisfactory food organisms for perch of intermediate size probably accounts for the slow growth and the poor condition of the fish in this lake.

PERCH CYCLE

There is some reason to believe, although the evidence is not conclusive, that a definite cycle with respect to age and size composition of the stock normally occurred in the population. When the fish were killed over three fourths were of the II group; the 0 and I groups were very poorly represented. It is possible that, because of the paucity of available food, the II group subsisted on the eggs or the young when these were available. Had the fish not been poisoned most of the II group would possibly have died of starvation in the following year, although enough adult fish would probably have survived to assure adequate reproduction. With most of the predators removed by starvation (see below) a large crop of young fish would possibly again have resulted. In such a cycle one age group would be very abundant, would keep down the two following age groups by eating the eggs or young, would die of starvation in its third year, and, in dying, would make possible the survival of another group. The dominant age groups in South Twin Lake for the ten years starting in 1934 would then have been (successively): II, 0, I, II, 0, I, II, 0, I, II, provided the cycle was uniform. The dominant group would invariably have been under legal size (six inches). In reply to a letter addressed to him, Mr. William Horsell, superintendent of the Pigeon River State Forest, stated that in the last eleven years the perch in South Twin Lake had always been small, six inches or less in length.

STARVATION

A number of factors suggest that ordinarily a majority of the fish may have died of starvation. Few fish other than young ones were normally removed by man or by predators, since the lake was fished very little and there were predators large enough to take the larger fish. Factors already mentioned which might suggest starvation of a considerable portion of the population are: (1) a decrease in condition in the III and IV groups combined; (2) the poor condition

of the population in general; (3) an unusually large head, especially in the groups in poorest condition; (4) small size of the food organisms in the stomachs, a fact that suggests an apparent scarcity of organisms of a size intermediate between Diptera and small perch (II group); (5) small amount of food in the stomachs (regurgitation may possibly have taken place, however, when the fish were poisoned); (6) apparent resorption of portions of the scales in many of the poorer individuals (see Pl. LXVI, Fig. 2); (7) unusually large proportion of relatively young fish (II group) in the population, despite the fact that cannibalism was probably relatively common. Although they were not studied in detail, a casual examination of the sex organs in the emaciated individuals indicated that in such fish the gonads were relatively very small. Although it cannot be proved definitely that many of the fish normally died of starvation, and although each of the items mentioned above may not in itself suggest starvation, the evidence, considered as a whole, indicates strongly that an inadequate food supply was responsible for an early mortality and a consequent scarcity of old fish.

GENERAL CHARACTERISTICS OF THE POPULATION

Gill nets, poison, and dynamite were employed to reduce in numbers (if possible, to exterminate completely) the perch population of South Twin Lake (Otsego County). Those perch which floated or which sank in shallow water were recovered and were studied by the writer. The study shows that: (1) a total of 955 perch per acre, weighing 29 pounds per acre, were definitely present — the actual number and weight were of course greater than the number accounted for and their weight; (2) 7 per cent were legal fish (54 males, 199 females); (3) the fish grew quite slowly; (4) over three fourths of those recovered belonged to age group II; (5) the proportion of females to males in the entire population was 74 to 100; (6) the young fish were dominantly males, the older ones dominantly females; (7) all fish over four winters old were females; (8) in general, the fish were in poor condition; (9) they had unusually large heads; (10) the fish covered a wide range of condition; (11) Diptera constituted the primary food item of the fish; (12) there was possibly a definite cycle with the dominant age group always of less than legal size; (13) there is some evidence to suggest that most of the fish normally died of starvation.

To what extent the concentration of the fish in South Twin Lake affected their growth and condition could not, of course, be determined. It should be pointed out, however, that this very dense population of perch has the slowest growth of all perch populations for which there are published records.

ACKNOWLEDGMENTS

The writer wishes to thank Dr. Ralph Hile of the United States Bureau of Fisheries and Dr. A. S. Hazzard, director of the Institute for Fisheries Research, for their helpful suggestions and criticisms.

UNIVERSITY OF MICHIGAN

LITERATURE CITED

- GEISER, S. W. 1924. The Differential Death-Rate of the Sexes among Animals, with a Suggested Explanation. Wash. Univ. Stud., Vol. XII; Sci. Series, No. 1: 73-96.
- HARKNESS, W. J. K. 1922. The Rate of Growth of the Yellow Perch in Lake Erie. Univ. Toronto Studies (Biol. Ser.). Publ. Ontario Fish. Res. Lab., 6: 87-97.
- HILE, RALPH. 1931. The Rate of Growth of Fishes in Indiana. Investigations of Indiana Lakes No. 2. Publ. No. 107, Dep. Conserv., State of Indiana, pp. 9-55.
- 1936. Age and Growth of the Cisco, *Leucichthys artedii* (Le Sueur), in the Lakes of the Northeastern Highlands, Wisconsin. Bull. U. S. Bur. Fish., No. 19: 211-317.
- JOBES, FRANK W. 1933. Preliminary Report on the Age and Growth of the Yellow Perch (*Perca flavescens* Mitchill) from Lake Erie, as Determined from a Study of Its Scales. Pap. Mich. Acad. Sci., Arts and Letters, 17: 643-652.
- JORDAN, DAVID STARR. 1929. Manual of the Vertebrate Animals, 13th Edition. World Book Co., xxxi + 446 pages.
- SCHNEBERGER, EDWARD. 1935. Growth of the Yellow Perch (*Perca flavescens* Mitchill) in Nebish, Silver and Weber Lakes, Vilas County, Wisconsin. Trans. Wis. Acad. Sci., Arts and Letters, 29: 103-130.
- VAN OOSTEN, JOHN. 1929. Life History of the Lake Herring (*Leucichthys artedii* Le Sueur) of Lake Huron as Revealed by Its Scales, with a Critique on the Scale Method. Bull. U. S. Bur. Fish., 44: 265-428.



FIG. 1. Perch of IV group (extremes). The two upper perch were too small



FIG. 2. Dorsal view of the same fish shown in Figure 1



1 2 3 4 5

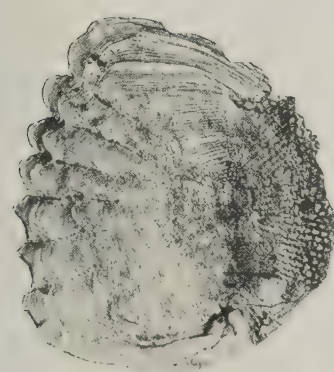


FIG. 2. Scale from slow-growing perch (IV group), indicating partial absorption of scales, with subsequent deposition of scale material

FIG. 1. Perch of II group, showing degrees of parasitism with strigoid larvae (tails retouched)

A PRELIMINARY REPORT ON THE PAST AND PRESENT STATUS OF THE MOOSE, *ALCES* *AMERICANA* (CLINTON), IN MICHIGAN

PAUL HICKIE

MOOSE SITUATION ON ISLE ROYALE

THE moose of Isle Royale have attracted much attention in recent years not only because of their large numbers, and because of their great size, the ease with which they are seen during the summer months, and those occasional times when they show fearlessness of man, but because the mysterious and romantic spell of places far away, difficult of access, and little known has provided the perfect backdrop for their doings on the island. When they first came to Isle Royale is a matter of conjecture, possibly in the winter of 1912-13, as many believe, possibly before, but their rapid increase in the decade following 1915 was readily apparent and widely known.

Dr. Adolph Murie (11), who investigated the moose situation in 1929 and 1930, was one of the first writers to point out the danger to the herd of food shortage, an almost inevitable consequence of herbivores in restricted areas and with no important predators, and states (p. 39): "On Isle Royale all of the important winter foods as well as several species eaten only in summer are overbrowsed." He points out the disappearance of water lilies and pondweeds, the exhaustion of ground hemlock, the heavy utilization of balsam fir, and the extensive overbrowsing on saplings and shrubs. He also mentions the presence of the spruce budworm and its deleterious effect on the balsams, one of the most important winter food plants of the moose on Isle Royale and elsewhere.

A large-scale map of the vegetation of the island was prepared by Dr. K. C. McMurry (10), head of the Geography Department of the University of Michigan, in 1930 and 1931, which likewise recorded widespread overbrowsing by moose.

J. H. Stephenson (17) and I. H. Bartlett, of the Game Division Staff, made a short survey in September, 1931, and reported a serious lack of winter forage.

This overbrowsing was not readily apparent to the lay observer, as is indicated by the writings of Ben East (6, pp. 39-40), who visited Isle Royale in February, 1932, to make winter pictures. Though he remarks on evidences of browsing seen, he did not believe food shortage was imminent, but admitted being unskilled in such matters and he preferred to rely on the judgment of others more experienced with big game and their problems. Less than two years later heavy depletion of the herd due, we believe, to malnutrition commenced.

Dr. Donald R. Coburn and the author (8) investigated conditions in the spring of 1934 and found or accounted for at least forty dead moose, several of which were suitable for autopsy. Many were young or middle-aged animals, so that death could not be ascribed to old age, and conditions suggested, almost unanimously, improper food and resultant starvation.

Later reports, during the summer of 1934, from inhabitants, resorters, and tourists, indicated a marked reduction from the numbers seen in the herd each year between 1922 and 1932, so that, after investigations in the summer and fall of 1934, a winter program of survey and experimentation was recommended to the Michigan Conservation Commission. It was approved and the work commenced in November, 1934, and carried through the winter to May 15, 1935.

One part of the program called for an attempt to live-trap moose on the island, hold them captive until navigation to the island, which is discontinued during the winter months, reopened in the spring, and then ship them to the Upper Peninsula of Michigan for restocking purposes. This was not a new idea, for in 1917 Oates (13, p. 29) stated that the Department was considering the transfer of a number of moose from Isle Royale to the Michigan mainland. As recently as 1932 tentative plans and budgets for this work had been prepared by J. H. Stephenson, of the Game Division Staff.

Our live-trapping and transporting experiment proved successful, and we were able to release nine moose at the Cusino Game Refuge near Munising in May, 1935. The release consisted of seven females and two males.

Their removal from Isle Royale could not be regarded as anything but desirable, for the feeding conditions are so severe that it is a question if within the range of any individual moose there is sufficient food of a suitable nature growing naturally to provide for it, but what justifies their release on the mainland? The following pages attempt to answer this question.

HISTORY

We know that the fur trade was the chief industry in Michigan from the middle of the seventeenth century until the middle of the nineteenth century, a period of two hundred years or more, when wild life was hunted and trapped intensively to produce fur for world-wide markets. We assume that during this time and the periods of lumbering and farming that followed most forms of wild life were reduced in numbers and some even exterminated by hunting or by removal of their habitats. Moose are now scarce in Michigan, and naturally the question arises, "Have they always been scarce, or were they once abundant and later reduced by too much hunting or cultural development?"

A search for early records of Cervidae in the literature of the seventeenth and eighteenth centuries, when white men were first exploring and settling in Michigan, is complicated by the fact that the newcomers, seeing resemblances in New World forms to the European game with which they were familiar, applied the Old World names. This might have proved satisfactory if care and exactitude had been used, but such was not the case. Thus arose the unfortunate application of the word "elk" to our American form which closely resembles the common European red deer (*Cervus elaphus*), while the form that was nearly identical with the European elk became "moose." To carry the thing to an almost absurd ending, the moose is sometimes known as "the flat-horned elk," while the wapiti is the "gray or round-horned moose."

One of the earliest and most interesting records of moose in the proximity of Michigan is found in the memoir of Nicolas Perrot (14, p. 126), which tells of Indians snaring twenty-four hundred moose (*élans*) on Manitoulin Island (Isle des Outaouas) in the winter of 1670-71. To illustrate the danger just mentioned, that of mistaking identities, we find Bailey (1, p. 40), in his account of Mackinaw, translating Perrot's French as "The Salteurs . . . secured more than two

thousand four hundred elks on . . . Manitoulin Island . . .," but since the original work uses *élan*, we are safe in calling them moose instead of elks.

About a century later, in the biography (3, p. 351) of a Chippewa Indian who hunted around the Montreal River south of the Apostle Islands, moose are listed as game, and the Indian tells of his encounter with an unfriendly bull moose which he killed with his knife tied to the end of a stick.

Writers in more recent times have found the moose scarce in Michigan. Little importance can be attached to its absence from the mammal list prepared by Dr. Abram Sager (9), state zoölogist, in 1839, for he includes only the animals he observed, but Dr. M. Miles (20, p. 222, footnote), also a state zoölogist, writes, in 1860: "The Moose is seldom seen within the limits of the State. Hunters inform me that it is still occasionally taken, but it is rapidly disappearing from its former haunts." It may be significant that at this time heavy inroads were being made on the forests of the state by lumbering.

Wood and Dice (21, pp. 468-469) have published several records of moose having been seen or taken since about 1880 in both the Upper and the Lower peninsulas, but they have no specimens from the Lower Peninsula. Hatt (7, p. 401) includes them on testimonial evidence in his list of mammals of Leelanau County as formerly present, and Creaser (4, p. 597) records for the same county two teeth and a portion of a maxilla.¹ Within the last few years several sight and specimen records from the Upper Peninsula have come to the Game Division, but these indicate widely scattered individuals or small groups of not more than three animals.

To summarize the history of the moose in Michigan, we may say that early records show they were commonly hunted in the northern part of the state, although possibly they were not so plentiful as in other areas to the east, north, and northwest; that the number of moose was very limited in the latter half of the nineteenth century, owing to one or more factors, such as unsuitability of habitat, excessive hunting, the so-called phenomenon of "drift," or some other unknown influence; and that they are probably as numerous now as they have been at any time during the last sixty years.

¹ Dr. Creaser states that on further examination this record proves to be of wapiti rather than of moose.

This historical background reassures us somewhat of the suitability of Michigan as a habitat for moose and, likewise, indicates that certain areas are, or can be made, favorable for them, but their scarcity in recent years shows that we should study the problem and do those things which are worth while and desirable to assure the success of our restocking experiment.

FOOD

Since the presence of proper feeding conditions is probably the most important factor in determining the range of moose in Michigan, one of the first things that should be undertaken is a study of the abundance and the suitability of browse. On Isle Royale, where winter food was generally insufficient, the moose moved about a great deal, probably searching for better areas, and when they failed to find them, many died of malnutrition; hence, if good browsing is not present in the region we wish to stock, we must try to make it available.

Scientists have long been familiar with the fact that in the Temperate Zone solid coniferous forests of large trees, or mature deciduous forests, support a very small quantity and variety of wild life. With no form is this relationship to the forest more apparent than with the moose. It is believed that an increase of moose in the Northern Peninsula has been brought about by the cutting off of some of the heavy timber and the creation of slash areas, with their great variety and abundance of tree shoots, shrubs, ferns, and herbs. Henry Bannon (2, p. 273) gives as the reason for the drift of the moose into the Cassiar country of British Columbia the heavy growths of willow and other brush that followed the forest fires which consumed the big timber. Raymond Thompson (18, p. 402) describes an area in the foothills of northern Alberta near Lake Athabaska, where it was not uncommon to count as many as two or three dozen moose in one day, as the finest moose country he had ever seen, and gives as the reason the destruction of the virgin timber by fires which had "paved the way for a rank growth of scrub birch, alder, and similar trees on which moose chiefly browse." On Isle Royale moose have frequented the "burns" which are covered with shrubby growths, small deciduous saplings, and young balsams until most of these plants are either browsed back to scraggly stems or destroyed entirely.

Time alone will tell when and whether it is necessary to provide "burn" or slash areas for the moose herd. The Game Division is now experimenting with "forage" cuttings for deer, that is, cutting a certain amount of a stand of trees at the critical period of the winter so that the deer may eat the tops, and at the same time provide a chance for a new growth to come up and furnish food for deer later on. No doubt moose would use these same areas if they were within range, but if not, it might be necessary to provide separate forage cuttings for them. Whenever this problem arises it will be found not only that it costs money to cut down trees, but that foresters may even feel that the trees are more valuable than the moose. This is not without precedent, for, according to Salvesen (15, p. 62), farmers in Norway say they would rather have wood than moose meat and hides. However, it should be pointed out that the species of trees moose prefer, balsam fir, birch, poplar, etc., are probably the least valuable of the forest species. In many places on Isle Royale moose have so completely destroyed the balsam that these areas are now growing solidly to spruce, a more valuable species, which the moose seldom touch.

Otto Schierbeck (16, pp. 28-29) sums up the discussion in his article "Forestry vs. Game Cover," in which he points out the dependence of big game species on the understory of the forest and the effect of fire, timber cutting, and the maturing of the forest as factors in creating or destroying this understory. He suggests that a guiding hand may be required to maintain the proper browse conditions and warns that at times such practice may not be compatible with the forestry principles of producing a maximum yield of valuable timber.

To the game men he says: "Have we as yet come to an understanding of the necessary browse area required by our different big game animals? Is there anyone who has yet prepared a list of the shrubs or plants which our big game animals prefer? Is there anyone who has made a study of the growing conditions of those shrubs which are so necessary to the welfare of our game or given a thought to the best methods of growing those shrubs or to the treatment of the forest in order to make them thrive?"

The answer to most of these queries is as yet in the negative, but we believe we have a fairly comprehensive list of the plants used by moose for food throughout the year on Isle Royale. It comprises

the work done by Murie (11, pp. 32-35); the studies made by the author in the winter of 1934-35, consisting of both field observations and feeding experiments; and lists and accounts from other sources. A list of twenty of the more important woody plants used

TABLE I

PARTIAL LIST OF WOODY PLANTS EATEN BY MOOSE AND DEER IN MICHIGAN,
WITH A PREFERENCE RATING FOR EACH *

Preference rating: A = Preferred; B = Freely eaten; C = Poorly eaten

Preference rating		Common name	Scientific name
Moose	Deer		
B	C	White pine	Pinus Strobus
A	C	Balsam fir	Abies balsamea
B	A	Arbor vitae	Thuja occidentalis
C	C	Juniper (procumbent)	Juniperus communis var. de- pressa
A	A	Ground hemlock	Taxus canadensis
A	C	Poplar (aspen)	Populus tremuloides
A	A	Birch (white)	Betula alba var. papyrifera
A	B	Willow	Salix species
B	B	Red oak	Quercus borealis
A	A	Mountain ash	Pyrus americana
A	A	Juneberry	Amelanchier species
B	C	Pin cherry	Prunus pennsylvanica
B	A	Hard maple	Acer saccharum
B	A	Mountain maple	Acer spicatum
B	A	Dogwood	Cornus stolonifera
B	A	Staghorn sumac	Rhus typhina
A	B	Honeysuckle	Lonicera species
Comparisons based on closely related species			
A	(No data)	Beaked hazel	Corylus rostrata
(No data)	B	Hazel	Corylus americana
A	(No data)	Salmonberry	Rubus parviflorus
(No data)	A	Raspberry	Rubus species
B	(No data)	Red-berried elder	Sambucus racemosa
(No data)	B	Common elder	Sambucus canadensis

* Murie (11) was used in part for the list of plants, but the author is responsible for the preference ratings given for moose. I. H. Bartlett, Game Division, Michigan Department of Conservation, rated the plants for deer preference.

by moose for browse, with a preference rating for each, is included here (Table I), but the actual production of suitable areas of browse is a far cry from a simple listing of plants.

Partly with this browsing problem in mind and partly to provide browse for our captive moose on Isle Royale, we cut an acre of more or less typical birch-poplar-balsam cover. The browse was cut from the felled trees, weighed, and fed to the moose, and the leftover brush was weighed when we removed it from the feeding racks. The trees on this acre averaged about three inches breast height, and there were 327 balsam firs, 630 white birches, and 26 poplars, as well as a few scattered trees of other species, a total of about a thousand. Four hundred and thirty-four small saplings and one hundred and twenty-five large trees, almost all of which were dead or entirely lacking in browse, were not counted in this total.

We cut and fed three and three-quarter tons of browse from this acre, of which the moose consumed roughly two tons. These studies showed that a moose requires approximately twenty-five pounds of browse a day, and indicated that a mixture of coniferous and deciduous browse was preferred to either one alone, for given a feeding of balsam alone, the moose showed a marked preference for deciduous browse at the next feeding and vice versa. There can be little doubt that a variety of food plants is necessary for the welfare of moose. Our figures are somewhat rough and incomplete, but they will serve as a basis for management procedures until more extensive and accurate data are available.

Competition for food brings up another consideration. Virginia deer and hares may be serious competitors, the latter only when they are very abundant. For comparison, the plants eaten by moose have been given a preference rating for both moose and deer. Analysis reveals (Table I) that there is no competition for five species, while for fifteen there is direct competition. On the whole, this is little more than an indication of rather close competition, for the lists on which this is based, and the ratings given each species require further study, from the standpoint of relative and seasonal abundance as well as of availability.

ENEMIES

The moose we release in the Upper Peninsula will encounter a certain number of natural and human enemies. The moose has little

to fear from its natural enemies: bears, wolves, dogs, and coyotes. The bears, which hibernate in winter, will not bother it in this period, when feeding and traveling are hard. Wolves, dogs, and coyotes, however, can and will trail it to some extent, but unless the snow is too deep and heavily crusted, a healthy moose is well able to take care of itself. None of these enemies is apt to bother the moose very much, but it is the human enemy and human culture which most menace the success of our program.

Poaching and "mistaking for a deer" are the most serious factors, if we are to judge from the experience of New York in trying to restock the Adirondacks with moose years after they had been shot out. The report of the Forest, Fish and Game Commission for 1906 (12, p. 303) gives as the reason for the failure of the experiment the fact that but fifteen moose were released, half of which were bulls, and that several of the cows were killed at the very outset of the work. With twenty-five to thirty thousand deer hunters in the Upper Peninsula of Michigan every year not many would have to make a mistake before our moose herd would be destroyed. Moose and deer are not difficult to tell apart, but neither are elk and deer, yet in 1935 at least five elk were killed near the Pigeon River Refuge during the deer-hunting season.

It is expected that hunting will be advisable after the herd has established itself, for without important predators or hunting to hold the moose population in check the area would become overstocked and the food supply exhausted, as has occurred on Isle Royale. We welcome the sportsman in the capacity of a reasonable check on overpopulation, yet we recognize that hunters must not be allowed to take so many moose that a suitable breeding stock is not left to replenish the herd annually.

DEPARTMENT OF CONSERVATION
LANSING, MICHIGAN

LITERATURE CITED

1. BAILEY, JOHN READ. 1904. Mackinac, Formerly Michilimackinac, A History and Guide Book, McMillan Ed., 5th revision, pp. 1-231, pls. and illus. The Richmond & Backus Co., Ann Arbor, Michigan.
2. BANNON, HENRY. 1918. In Cassiar, the New Game Country. Forest and Stream, Feb.-May, pp. 73-77, 144, 145, 173-175, 206, 207, 240, 241, 272, 273.

3. CHAPMAN, C. H. 1902. The Historic Johnston Family of the "Soo." Mich. Hist. Coll., 32: 305-353.
4. CREASER, CHARLES W. 1935. The Moose (*Alces americanus*) and the Water Shrew (*Sorex palustris hydrobodistes*), Rare Mammals of the Southern Peninsula of Michigan. Pap. Mich. Acad. Sci., Arts and Letters, 20 (1934): 597-598.
5. DABLON, CLAUDE. 1861. Relation de la Nouvelle France, pp. 1-219. Jean-Marie Shea, Cramoisy Press, Nouvelle York.
6. EAST, BEN. 1932. Winter Moose Trails. Field and Stream, Sept., pp. 38-40, 61.
7. HATT, ROBERT TORRENS. 1924. Land Vertebrate Communities of Western Leelanau County, Michigan. Pap. Mich. Acad. Sci., Arts and Letters, 3 (1923): 369-402.
8. HICKIE, PAUL, AND COBURN, DONALD R. Unpublished manuscript, Game Division Report on the Moose of Isle Royale, Sept., 1934. Game Division, Department of Conservation, State of Michigan, Lansing, Michigan.
9. HOUGHTON, DOUGLASS. 1928. Second Annual Report of the Geological Survey of Michigan. Mich. Hist. Comm., Lansing, Michigan. Sager's report is on pages 209-223.
10. McMURRY, K. C. Unpublished manuscript, Dept. Geog., University of Michigan, Ann Arbor, Michigan.
11. MURIE, ADOLPH. 1934. The Moose of Isle Royale. Misc. Publ. Museum Zoology, University of Michigan, No. 25: 1-44, frontispiece, 6 pls.
12. New York State, Forest, Fish and Game Commission. 1907. Tenth Annual Report (1906). Albany, New York.
13. OATES, WM. R. 1917. Michigan: Game and Fish. Biennial Report, 1915-16, State Game, Fish and Forest Fire Department of the Public Domain Commission, pp. 1-100, pls. and charts. Lansing, Michigan.
14. PERROT, NICOLAS. 1864. Mémoire sur les mœurs, coutumes et religion des sauvages de l'Amérique septentrionale, pp. 1-156, notes 157-337, additions 338-341. A. Franck, Leipzig and Paris.
15. SALVESEN, SIGVALD. 1929. The Moose and Red Deer in Norway. Journ. Mammal., 10: 59-62.
16. SCHIERBECK, OTTO. 1931. Forestry vs. Game Cover. Canadian Field-Naturalist, 45: 28-30.
17. STEPHENSON, J. H. Unpublished manuscript. Report of Isle Royale Trip, Sept., 1931. Game Division, Department of Conservation, State of Michigan, Lansing, Michigan.
18. THOMPSON, RAYMOND. 1932. Trailing with an Old Trapper. III. Canadian Forests and Outdoors, Nov., pp. 400-402, 410.
19. THWAITES, REUBEN GOLD. 1899. The Jesuit Relations and Allied Documents, 56: 9-304. The Burrows Bros. Co., Cleveland.

20. WINCHELL, ALEXANDER. 1861. First Biennial Report of the Progress of the Geological Survey of Michigan, Part II, Zoology, pp. 211-241.
21. WOOD, NORMAN A., AND DICE, L. R. 1924. Records of the Distribution of Michigan Mammals. Pap. Mich. Acad. Sci., Arts and Letters, 3 (1923): 425-469.

FURTHER OBSERVATIONS AND STATISTICS ON THE FLIGHT OF FISHES

CARL L. HUBBS

CONTENTS

I. Introduction.....	641
II. The mechanism of flight by the typical flying fishes (<i>Parexocoetus</i> and the Cypselurinae)	642
III. Relation between direction of wind and direction of flight	644
IV. Observations on flying fish at night	649
V. Abundance of flying fish	650
VI. The number of successive leaps	653
VII. Duration of flights	654
VIII. Summary	658
Supplementary note	659
Literature cited	660

I. INTRODUCTION

THE need for a statistical approach to the problem of the flight of fishes was pointed out by Breder in 1929. In the same year I made observations on the basis of which a critical discussion and a statistical analysis of the flight of the Exocoetidae were attempted (Hubbs, 1933). The aim was to add some degree of objectivity and precision to the study of this interesting question, which has ordinarily been approached in a superficial, uncritical, nonquantitative manner. The conclusions of that paper, since they were based largely on observations made with new methods in East Indian and Philippine seas, have needed the confirmation of additional observations and records made in other waters.

An opportunity to collect such obviously needed additional data on the flight of fishes presented itself early in 1935, when I traveled across parts of the Gulf of Mexico and the Caribbean Sea, from New Orleans to Puerto Barrios, Guatemala, between January 30 and February 2, and from Tela, Honduras, to New Orleans, between

May 6 and 8. My companion on the Carnegie Institution of Washington—University of Michigan Expedition to Guatemala in 1935, Dr. Henry van der Schalie, assistant curator of mollusks in the Museum of Zoölogy of the University of Michigan, generously assisted in taking the numerous records on these two steamer trips. Some further data, on the flight of the California flying fish, were obtained on a previous trip, in 1934.

For permission to quote from their pertinent field notes on the flight of fishes thanks are expressed to S. C. Brooks, H. Walton Clark, Thomas Barbour, and C. M. Breder, Jr.

II. THE MECHANISM OF FLIGHT BY THE TYPICAL FLYING FISHES (*Parexocoetus* AND THE CYPSELURINAE)

The new observations being reported in this paper confirm our previous statements on the mechanism of flight by *Parexocoetus* and the Cypselurinae.

A considerable number of California flying fish, watched from a launch just south of Santa Cruz Island, California, on August 28 and 29, 1934, were seen to fly essentially as previously described (Jordan, 1907, and other papers; Hubbs, 1918; Loeb, 1936). The folding of the fins just before the end of the flight, the use of the pelvic fins as stabilizing and balancing planes, and the use of the caudal fin as a vertical rudder in the air were not again observed, but no very large number of the fish were seen in the air, and I was in a rather unhappy condition for making detailed observations.

Breder's observations (1929, p. 307) on Atlantic species and mine on the California species, in regard to length of flight as related to direction of wind, were not, as he thought, entirely contradictory. Writing, in 1918, "when flying with the wind, distances of about a quarter mile are occasionally made," I referred to flights in which the fish took off into the wind, then seemingly tacked into it much as a soaring albatross does in following a ship, finally swerving around so far as almost to float along with the strong wind before the end of the long flight. The smaller flying fishes seldom seem to control their long flights so accurately or so effectively.

The smaller flying fish of the Gulf of Mexico and the Yucatan Channel — for instance those 15 to 25 cm. long seen near 25° N. Lat., 88° W. Long., on January 30, 1935 — many but not all of which

seemed referable to *Parexocoetus*, taxied on the average less than 6 meters in gaining momentum for a flight, and not infrequently rose directly from the sea to make short leaps of about 2 to 7 meters. In these respects the Gulf flying fish behaved like the Atlantic species of *Parexocoetus* observed and recorded by Breder (1929, p. 309). The generally larger Pacific species referable to *Cypselurus* (*sensu latu*) which I observed very seldom leaped directly from the water, and they taxied on the average for longer distances. The Gulf of Mexico fish agreed with those of the Pacific in always making a definite taxi before a really long flight. Most of the taxiless flights were started very close to the ship, as though the fish had been too suddenly frightened to take off normally. Such direct leaps resembled the air vault of a *Mugil* or a *Coryphaena* more closely than the real flight of a flying fish.

The flying fish observed south of the Yucatan Channel (in the Caribbean Sea), apparently mostly *Cypselurus* and immediate allies rather than *Parexocoetus*, seemed to skim the waves more accurately, showing better vertical control of flight. They varied in estimated length from 12 to 38 cm. In this region the flights were almost invariably preceded by a taxi. This was apparent at all times, but was most strikingly seen in the early morning and in the evening, when, because the light came from near the horizon, the taxi tracks were very conspicuous on the surface, often being observed when the fish themselves could not be discerned.

In every flight carefully watched in the Gulf of Mexico and Caribbean Sea the pectoral and the pelvic fins (wings or planes) were both held taut and motionless while the fish was in the air. The only motion of the pectoral fins seen was the vibration of slight amplitude, which certainly seemed a mere physical response to the effective motive activity, the side-to-side lashing of the tail as the fish taxied away for a flight. The simultaneous vibration of the body and wing tips as the tail swept back and forth at the surface and the knifelike rigidity of the planes during the actual soar were seen with uncommon clearness when a fish rose a few feet ahead of a launch on which I was riding in Belize Bay and flew away straight forward, so that its apparent motion was very slight.

A still more favorable opportunity for the observation of the method of flight by exocoetids was once experienced by Dr. Thomas Barbour, who writes to me as follows:

Once in a small power skiff off Watlings Island we ran out into a very heavy swell, left over from a big blow, not breaking at all but putting us in the situation of having a green wall of water higher than my head on each side of the launch, as we would run along from time to time in a trough between two seas. Now I could look right through these waves, or water walls, when the light was exactly right, and I saw flying fish take off and fly on many occasions, some of them passing so close to my face that it would have been no trick to catch them with a short-handled net, which, needless to say, I did not have. It was, however, a most perfect opportunity to see the way the fish planed that anyone could possibly ask for and not one of them flopped its wings, even in salute.

My previous indication (1929, pp. 588-590) that the vibration of the tail during the taxi is very rapid was confirmed in Yucatan Channel on January 31, 1935, when I distinctly heard a rather high-pitched note produced by the tail movements of flying fish taxiing away in schools.

Mills' claim (1936*a*, 1936*b*) that flying fish intentionally lower their tails in preparation for a new taxi records a tendency which, contrary to his statement, I also observed, without, however, attempting to judge in any way the fish's intentions.

The longer taxis observed in the Gulf of Mexico, comparing favorably with those seen in the Pacific, seemed to last about one second. One long third taxi of a compound flight was closely timed by stop watch as 1.0 second.

Observations by Professor S. C. Brooks (sent, with permission to quote, in a letter dated June 25, 1933) bear on the question of the speed obtained by flying fish in their flights. The strongest flyers of the equatorial current, large lavender-winged fish approaching 50 cm. in length, easily outsped the boat, which was making 17 to 18 knots. He estimated their take-off speed as between 30 and 40 statute miles per hour, in rough agreement with other estimates.

III. RELATION BETWEEN DIRECTION OF WIND AND DIRECTION OF FLIGHT

In a previous contribution (Hubbs, 1933, p. 595) I stated: "The claim has been made that flying fishes invariably take off into the wind, but I have seen them scoot away toward all points of the compass while a strong wind remained in one quarter." This statement rather opposed the indication by Breder (1929, pp. 307, 311) that flying fish ordinarily, like airplanes, take off into the wind. Breder wrote: "Totalling those from the windward side we get 230 and those from the lee 85 or, in other words, nearly three times as many

flew into the wind as with it." My 1935 observations prove the correctness of the general view supported by Breder. Possibly the Atlantic species take off into the wind much oftener than do the Pacific forms, on which my earlier observations were made. More probably, however, my conclusion, quoted above, unduly emphasized the exceptional flights made with the wind, and was impressed on my mind after observing the indiscriminate direction of flight on virtually windless days, when the sea was glassy-smooth.

Our first test of the relation between direction of wind and direction of flight gave very definite results. This test was made in the Gulf of Mexico at about 25° 15' N. Lat., 88° 00' W. Long., from 10:15 to 11:45 A.M. on January 30, 1935. The direction of movement of ship, of wind, of whitecaps, and of the flights, as well as compass bearing, are all shown in Figure 21A. There was little swell, running at nearly right angles to a fresh breeze, throwing up a few irregular whitecaps; the sky was overcast at first, but later was clear; the *Sargassum* was thin and in small clumps. The observations were made in a balanced way by Dr. van der Schalie and myself, watching simultaneously from either side of the bow and changing sides several times to avoid a personal error. Of the 178 fish counted flying to windward, including several flocks of from 5 to 20, about 95 per cent took off at nearly right angles to the ship, in the sector shown in the figure, from various places between a point 5 meters ahead of the extreme bow and a point 12 meters behind the bow; some flew slightly forward; many made compound flights. On the leeward side the four fish that were seen to rise all headed straight forward at the start of their flight, and three tended to round the bow, swinging into the wind as shown in the figure; none of the four made a compound flight. Clearly the flying fish showed an extremely strong tendency to take off into the wind.

This tendency of the flying fish to take off and fly into the wind was further indicated by a second series of observations, made during the afternoon of the same day about 40 miles farther south. The conditions, diagramed in Figure 21B, differed in that the wind had shifted so that its direction fluctuated from the port beam to the port stern, instead of from the port bow to the port beam, and the whitecaps were now more nearly at right angles with the wind. In apparent consequence, the fish now took off from any point opposite the front half of the ship's length, and showed as much

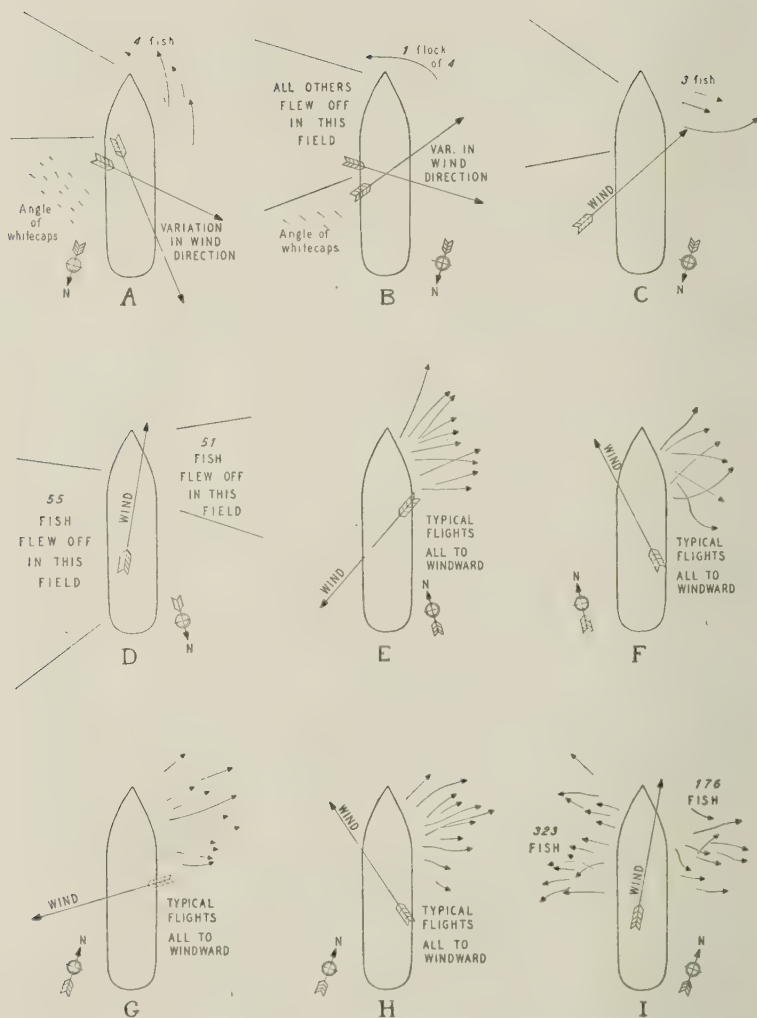


FIG. 21. Directions taken in flight by flying fish frightened into the air by a steamer, as related to direction of wind. For detailed discussion see text. In A 95 per cent of the fish flew off to windward in the sector indicated. In C 46 fish flew off to windward in the sector indicated

tendency to fly slightly backward as slightly forward to the ship's direction. Although no accurate counting was attempted on this occasion, it was clear that almost all the many fish seen flying again rose on the windward side. The only ones seen flying on the lee side comprised a flock of four, which rose from near the bow of the ship, first heading forward, but almost immediately swerving to the windward, rounding the bow.

Even when the fish were flying more abundantly later in the same afternoon not one was seen to fly to leeward, or to round the ship's bow so as to head into the wind. A very few rose on the lee side to fly straight forward parallel with the ship's course. Most of the fish observed throughout the whole day soared off roughly at right angles with the ship. The length of these fish, many of which seemed to be *Parexocoetes*, varied from about 15 to 25 cm.

Two series of counts of flight direction made on January 31, 1935, from 7:15 to 8:15 A.M. and from 11:30 A.M. to 12:30 P.M., in the Yucatan Channel, further confirmed the view that flying fish fly into the wind. The first series was made at about 21° 15' N. Lat., 86° 34' W. Long.; the mean location for the second series was the noon position of 20° 18' N. Lat., 86° 40' W. Long. The counts of fish rising to windward and leeward and the direction taken in flight differed sharply, in obvious relation to the direction of the wind (Figs. 21C-D). So long as the wind, though from the stern, remained very distinctly on the port side, most of the fish (46) flew off more or less at right angles to the vessel from the port side of the front half; the three that flew on the starboard side, instead of heading forward and rounding the bow as previously, made off at right angles, in flights of 1, 2, and 3 leaps respectively. But when the wind shifted into an almost strictly stern direction, the fish took off and flew in about equal numbers to port and to starboard. The wind came from a few points to the port, and slightly more fish (55) flew to port than to starboard (51). Furthermore, the fish rising to the port or slightly windward side arose from various points along the rear two thirds of the boat, and showed a strong tendency to fly off or to swerve toward the rear, that is, into the wind. Those that rose on the starboard or slightly lee side rose from the front half of the ship, and made off more or less at right angles. For some time previous to and following the second series of counts, the same wind condition prevailed, and the fish flew in a similar direction.

Observations confirming the view that flying fish take off into the wind were made on the northbound journey from Tela, Honduras, to New Orleans. Typical flights, all to windward, were sketched on five occasions, as shown in Figures 21E-I. Figure E illustrates flights as observed on May 6, 1935, in the Caribbean Sea north of Tela during the morning and about noon, when the position was $16^{\circ} 44' \text{ N. Lat.}, 87^{\circ} 16' \text{ W. Long.}$; there were a moderate breeze, a fairly heavy swell, and a choppy sea. Figures 21F-G show flights observed on May 7, 1935, at about 6:30 and 8:00 A.M., in the Yucatan Channel, at about $21^{\circ} 00' \text{ N. Lat.}, 86^{\circ} 10' \text{ W. Long.}$, and $21^{\circ} 20' \text{ N. Lat.}, 86^{\circ} 10' \text{ W. Long.}$, respectively; Figure 21H shows flights seen about 3:00 P.M. of the same day, north of Yucatan, at about $22^{\circ} 55' \text{ N. Lat.}, 86^{\circ} 46' \text{ W. Long.}$; during this day the sky was mostly cloudy, and a moderate east breeze and sea were recorded.

As on the southward trip, the fish flew toward both sides when the wind shifted to a direction approaching that taken by the ship. This condition obtained in the Gulf of Mexico, early on May 8, 1935, at about $26^{\circ} 35' \text{ N. Lat.}, 88^{\circ} 15' \text{ W. Long.}$ There was a light swell, a slightly choppy surface, but almost no whitecaps. Dark glasses were used to avoid the early morning sun glare. The directions of ship, of the wind, and of the flights are shown in Figure 21I. The results of the observations were as follows:

<i>Time</i>	<i>Counts of all fish seen flying to port (west)</i>	<i>Counts of all fish seen flying to starboard (east)</i>
6:10-6:35 A.M.	195 (counted by Hubbs)	90 (counted by van der Schalie)
6:35-7:00 A.M.	128 (counted by van der Schalie)	86 (counted by Hubbs)

A total of 323 fish flew to port, slightly into the wind; 176 to starboard, slightly with the wind.

The two sets of observations showing that flying fish make off in both directions when the wind is nearly in line with the boat suffice to indicate that no importance may be attributed to the circumstance that they took off and flew almost exclusively to the eastward in the other observations cited above.

The observations revealed that most fish flew eastward into the wind at all times during daylight, from early morning until late afternoon, as the ship plied southward and also northward. Since the direction of light was reversed about noon, we conclude, with

Breder (1929, pp. 309-310), that the direction of sunlight is not a dominant factor in determining the direction of flight during the day.

The stimulus responsible for directing the flight into the wind must usually operate under water before the fish break the surface, for those observed maintained a straight line as they emerged, taxied to gain speed, and rose into the wind. They emerged on the lee side as seldom as they flew on this side.

The reason why fish fly away from a ship to windward we may assume to be either: (1) because those on that side are more frightened, owing perhaps to vibrations rebounding from the splash of waves against the windward side of the ship; or (2) because they possess reactions which induce them when disturbed to take off into the wind, and inhibit them from taking off with the wind. Or both reasons may operate.

No thoroughly satisfactory explanation has been given concerning the nature of the underwater stimulus which almost unerringly acquaints the fish with the direction of the wind above the surface, causing it to emerge and to fly off into the wind. The swiftness of the underwater movements of the fish complicates the problem of understanding how it perceives the subaqueous directional stimulus. Breder (1929, pp. 307-308) suggests that the wave motion of water particles is the critical stimulus. Visual response to surface wave movements is another possibility, confirmed, though very imperfectly, by the observation, in the Gulf of Mexico, of two fish flying off at night from the leeward side of the ship, whereas none was seen at night on the windward side. It is quite possible, however, that these two fish had been attracted to the lights of the ship, had struck it without being mortally injured, and were flying off again when seen.

IV. OBSERVATIONS ON FLYING FISH AT NIGHT

The observation just recorded shows that flying fish at least occasionally fly at night. Many reports, furthermore, have been made of their lighting on the decks of vessels at night. It has also been observed that flying fish, exhibiting a very strongly positive phototropism, gather rapidly about a surface light. In a cove on the south side of Anacapa Island, California, on the night of August 29, 1934, a strong electric light hung in a reflector just above the water

surface attracted at first scores and finally several hundred uniformly large adults of *Cypselurus californicus*. They seemed to be dazed as well as attracted by the light, for they frequently rammed the side of the boat, which they almost never do in the daytime. Most of them struck the boat while rushing about just under the surface, but some hit the side while flying or skipping. The fish thus injured, some slightly stunned, others seriously or even mortally wounded, sluggishly swam about near the light, so that they were very easily captured by spear or dip net. They occasionally made short, sporadic flights and surface skips, far below the standard of their strong diurnal flights (Hubbs, 1918). Many, but perhaps only the injured ones, held their pectoral fins more or less widely spread as they lazily moved about under water, or before they reached the water surface — apparently also in contrast with their diurnal habits.

That other species of flying fish show very similar behavior under a light at night is indicated by the following observations kindly sent to me by Mr. H. Walton Clark, of the California Academy of Sciences:

On May 29, 1932, while anchored off Marshall Point, Albermarle Island, Galapagos, we hung near the surface of the water an electric light which attracted a great school of pink-winged flying fish. The light apparently blinded the fish, for many dashed against the side of the yacht, knocking themselves unconscious or killing themselves, so that there were a number of corpses floating on the surface. I think most of the fish had been stunned or killed while under the water or at the surface before flying. I often saw them open the pectoral fins just a moment before leaving the water — that is, at night about the light. I have never seen them strike a boat in daytime, although they occasionally came on deck, one striking Mr. Swarth a sharp blow on the shoulder while he was seated at lunch.

Similar observations on the reactions of flying fish to a light at night were published by Breder (1934, pp. 34–35), Loeb (1936, p. 261), and others.

V. ABUNDANCE OF FLYING FISH

Our four actual counts of all flying fish observed during stated periods of time are given again in Table I, in a form and with calculations to agree as closely as possible with Breder's figures on the number of flying fish observed at different places under varying conditions, and his calculation of the population per square mile (Breder, 1929, Table I and text). Our counts, all made by two persons, are not wholly comparable with those of Breder because

TABLE I

DATA ON THE ABUNDANCE OF FLYING FISH

The data are given and computations made as nearly as possible to agree with the method recommended by Breder. In computing the population per square mile according to Breder's formula for two observers (1929, p. 301), *D* was assumed to be 40; *B*, 50; *K*, 12.5 (all rough approximations).

Obs. no.	Date, 1935	Hour	Approximate position		Breeze	Swell	White- caps	Sky	No. of fish counted		No. per half hour	Calculated population
			N. Lat. $\times$ W. Long.						Port	Starb.		
1	Jan. 30	10:15 to 11:45 A.M.	25° 15' $\times$ 88° 00'		fresh	little	few	overcast to clear	178	4	61	456
2	Jan. 31	7:15 to 8:15 A.M.	21° 15' $\times$ 86° 34'		gentle	moderate	few	clear	46	3	25	187
3	Jan. 31	11:30 A.M. to 12:30 P.M.	20° 18' $\times$ 86° 40'		gentle light	"small" light	many almost none	clear clear	55 323	51 176	53 299	397 2238
4	May 8	6:10 to 7:00 A.M.	26° 35' $\times$ 88° 15'									

we did not restrict our count to fish which rose within the arbitrarily defined limit of the ship's disturbance ("the curl of the bow wave," approximately fifty feet from the ship). Therefore our figures are somewhat higher than they would have been had they been made by his method, but not very greatly so, because most fish rose near the ship.

The calculation of the population per square mile by the method used by Breder can hardly be expected to give very exact data, because we have no proof that all flying fish within fifty feet of the ship rise into the air. The fact that very few rise to the lee of a beam wind suggests that by no means all fly when disturbed by the ship. A stern wind which causes them to fly off to both sides might well be expected to lead to a higher count and hence a higher estimated population than would a beam wind in the same locality. Our count of 299 fish per half-hour observation obtained on May 8 in the Gulf of Mexico, much higher than the maximum given by Breder (1934, p. 33), was made when the fish were flying to both sides.

The percentage of the fish near the ship's course which take to flight may vary greatly with a variety of physical conditions. The enormous fluctuations from hour to hour in the number seen indicates that some meteorological conditions may be related to the flying propensity. For instance, large numbers were observed in the early morning of May 8, when 499 were counted flying in the fifty minutes before 7:00 A.M., whereas on the same day there were half-hour periods when not more than a dozen were seen in the air. Similar fluctuations in abundance of the fish (in the air) were noted in the East Indian region, where at times, as I now recall, it was not uncommon to see 500 or more per half-hour periods more or less interspersed with periods when very few fish were taking to flight.

Since the calculated figures can hardly be expected to give exact, absolute values of the population of flying fish per square mile and since they are of value chiefly as relative figures, it is proposed that the number of fish seen flying in each half-hour period of observation be used for the purpose of analyzing geographical variation in their abundance. The fish rising more than 50 feet from the vessel should, we believe, also be included, for these are obviously frightened by the ship, since many rise to windward in the belt from 50 to 300 feet distant, while few rise to leeward in this belt. Furthermore

many of those rising about 100 feet from the ship may well have been frightened away from a position very close to it, but have swum that distance under water before taking to the air.

The great fluctuation observed from hour to hour in the number of fish driven into the air by the steamer indicates that it would be very difficult to determine their geographical variation in abundance by plotting even a large number of accurate counts. Of course, certain areas of marked scarcity and of outstanding abundance could be so indicated. Numerous counts on our 1935 trip, for example, would have suggested a very low concentration near the Mississippi delta and close to the coral reefs and beaches of British Honduras, Guatemala, and Honduras, but relative abundance in the open, western parts of the Gulf of Mexico and the Caribbean Sea and the connecting Yucatan Channel. In these waters, however, the exocoetids were by no means uniformly indicated as abundant, for almost none flew for considerable periods between times when many were on wing.

VI. THE NUMBER OF SUCCESSIVE LEAPS

The tendency of typical flying fishes (*Parexocoetus* and *Cypselurinae*) to prolong their flights by making more than one leap has been repeatedly noticed and discussed, for instance, by Breder (1929), Hubbs (1933, 1935), Mills (1936*a*, 1936*b*), and Forbes (1936), among recent writers on fish flight. Breder recorded 29 apparently selected counts of the "number of touches" (= intermediate taxis, or number of leaps minus one). Hubbs gave 299 counts made by random selection about the Philippine Islands. When analyzed according to varying conditions of observation, these figures indicated that the number of leaps per flight was uniform and virtually independent of wind and sea and size and species of fish.

The 447 new counts, made in the Gulf of Mexico and the Caribbean Sea in January, February, and May, 1935, are presented in Table II. These give a somewhat higher average, 2.4 versus 2.0, than the counts made in the Philippine waters, summarized in the same table. The distribution of the counts, however, is remarkably similar, indicating further a uniformity in the characteristics of flight throughout the typical flying fishes. The maximum number of successive leaps observed in the Atlantic was 11; in the Pacific, 12. The relatively few counts for the California flying fish, made on Au-

TABLE II
NUMBER OF SUCCESSIVE LEAPS IN FLIGHT OF FLYING FISH

Locality	Number of leaps in flight												Total	Av.
	1	2	3	4	5	6	7	8	9	10	11	12		
Gulf of Mexico and Caribbean Sea...	210	75	62	34	28	20	10	5	2	..	1	..	447	2.4
Santa Cruz Island, California.....	18	2	2	1	..	..	..	..	..	..	..	..	23	1.4
Philippine Islands	164	63	30	23	5	5	3	2	..	3	..	1	299	2.0

gust 28 and 29, 1934, just south of Santa Cruz Island, California, and given in the same table, although hardly sufficient to yield a significant average, do suggest that the huge *Cypselurus californicus* less

TABLE III
RELATION OF SIZE OF FISH TO NUMBER OF LEAPS IN FLIGHT
Data for Gulf of Mexico and Caribbean Sea, 1935

Estimated size of fish	Number of leaps in flight									Total	Av.
	1	2	3	4	5	6	7	8	9		
Small, 15 to 20 cm. . .	10	5	1	2	1	2	1	..	..	22	2.5
Medium, 20 to 25 cm.	36	12	8	3	2	2	1	1	1	66	2.2
Large, 25 to 35 cm. . .	20	3	10	3	2	2	2	..	..	42	2.5

often indulges in compound flights than do smaller species of the group. In the Gulf of Mexico and the Caribbean Sea, however, there seemed to be no significant differences in the number of leaps taken by the small, medium, and large fish observed (Table III).

VII. DURATION OF FLIGHTS

Breder (1929, pp. 304, 310) published the first data of consequence on the length in seconds of the flight of flying fishes, basing his 29 observations on Atlantic species. Hubbs (1933, pp. 596-599, and fig. 67) followed with 424 timings of the duration of flights or parts of flights in Asiatic waters. Our new observations, involving the timing of 195 flights in the Gulf of Mexico and the Caribbean Sea in 1935, are presented in Table IV, along with the comparable

TABLE IV

LENGTH IN SECONDS OF FLIGHT OF FLYING FISH

The time was measured for both simple and compound flights, from the moment the fish left the water at the completion of the initial taxi until it reentered the water, and therefore includes the intermediate taxi periods. The figures outside parentheses are for the western Atlantic; those within parentheses are for the western Pacific. In the western Atlantic the times were recorded to tenths of a second, and the averages were computed from the original, unclassified data.

Time to nearest second	Number of leaps in flight								
	1	2	3	4	5	6	7	8	9
0	16(1)	2(..)	1(..)	.....	.....	.....	.....	.....	.....
1	21(14)	6(2)	..(1)	.....	.....	.....	.....	.....	.....
2	12(18)	1(1)	2(1)	.....	.....	.....	.....	.....	.....
3	13(7)	4(4)	4(1)	.....	1(..)	..(1)	.....	.....	.....
4	12(2)	5(2)	2(..)	1(..)	.....	.....	.....	.....	.....
5	10(2)	1(2)	4(1)	2(..)	1(..)	.....	.....	.....	.....
6	6(3)	3(1)	3(..)	1(..)	2(..)	.....	.....	.....	.....
7	2(1)	2(2)	3(1)	2(..)	.....	2(..)	1(..)	.....	.....
8	1(1)	1(..)	4(..)	3(1)	2(..)	2(..)	..(1)	.....	2(..)
9	..(1)	2(1)	1(2)	.....	..(1)	2(..)	1(..)	.....	.....
10	..(1)	1(1)	1(1)	2(1)	3(..)	1(..)	1(..)	1(..)	.....
11	.....	.....	3(..)	..(1)	.....	2(..)	.....	1(..)	.....
12	..(1)	.....	.....	1(1)	1(..)	.....	1(..)	1(..)	.....
13	1(1)	..(2)	.....	..(2)	.....	.....	.....	.....	.....
14	.....	1(..)	..(1)	.....	.....	.....	.....	.....	.....
15	.....	.....	.....	.....	.....	.....	.....	1(..)	.....
16	.....	.....	..(2)	.....	.....	.....	1(..)	.....	.....
17	.....	.....	.....	1(..)	.....	1(..)	.....	.....	.....
18	.....	.....	.....	.....	.....	.....	.....	.....	.....
19	.....	.....	.....	.....	.....	..(1)	.....	.....	.....
20	.....	.....	.....	.....	.....	.....	.....	.....	.....
21	.....	.....	.....	.....	.....	.....	.....	.....	.....
22	.....	.....	.....	..(1)	.....	.....	.....	.....	.....
23	.....	.....	.....	.....	.....	.....	.....	..(1)	.....
24	.....	.....	.....	.....	.....	.....	.....	.....	.....
25	.....	.....	.....	.....	.....	.....	.....	.....	.....
26	.....	.....	.....	.....	.....	.....	.....	.....	.....
27	.....	.....	.....	.....	.....	.....	.....	.....	.....
28	.....	.....	.....	..(1)	.....	.....	.....	.....	.....
Total speci- mens	94(53)	29(18)	28(11)	13(8)	10(1)	10(2)	5(1)	4(1)	2(..)
Average time in seconds	2.7(3.2)	4.4(5.5)	6.0(8.4)	8.1(14.4)	7.9(9?)	9.7(11?)	10.7(8?)	12.0(23?)	7.9?(..)

figures for the western Pacific (the latter in parentheses). The longest single-leap flight timed in the western Atlantic lasted 13 seconds, as in the western Pacific. The duration of the compound flights lasting longer than 13 seconds was 14, 15, 16, 17, and 17 seconds in my Atlantic observations, and 14, 16, 16, 19, 22, 23, and 28 seconds in my Pacific ones. Commenting on his observations made on the *Atlantis* expedition of 1934, Breder (1934, p. 33) wrote that:

The longest timed [compound] flight amounted to not quite twenty seconds, during which time a surprising distance can be covered. However, much longer flights are sometimes to be observed.

Breder stated (in a letter) that some untimed compound flights certainly lasted longer than 20 seconds, though none approached the record flight of 42 seconds timed by Captain B. W. Leek (reported by Breder, 1929, p. 310). One flight of four leaps, made by a California flying fish (*Cypselurus californicus*) just south of Santa Cruz Island, California, on August 29, 1934, was timed by me with a stop watch as of 14 seconds duration. Professor S. C. Brooks, who spent many hours watching and timing flying fish on a trip to Tahiti, and also about Panama, Cuba, and other lands, wrote (in a letter, June 25, 1933) that the longest flight timed by him lasted 24 seconds. These observations on the duration of the longer flights in the Atlantic and in the Pacific are in good agreement.

The flights in the Atlantic, however, as shown in the bottom row of Table IV, averaged briefer, for each given number of leaps in the flight, than those in the western Pacific. The difference in the observed duration of flights in the two oceans was apparently due to the difference in the size of the fish. The comparable timings on the Pacific species were made in a region, east and northeast of Luzon, where most of the fish were very large, being 25 to 45 cm. long. About two thirds of the Atlantic fish whose flights were timed were estimated to be only 15 to 25 cm. long. Contrary to the conclusion in my earlier report (Hubbs, 1933, p. 609), which was not justified by the data presented in Table I of that paper, it now becomes evident that the larger fish on the average make longer flights than do smaller ones (see Table V of this paper). This revised judgment is in line with the conclusion by Breder (1929, p. 310), which, however, was based on hardly sufficient data.

Professor S. C. Brook's unpublished observations indicated that

TABLE V

RELATION OF SIZE OF FISH TO DURATION OF FLIGHT

For the western Atlantic records the durations of the flights were determined with a stop watch, and were originally recorded to tenths of a second; the averages were computed from the original, unclassified data. The figures for the western Pacific are taken from Hubbs (1929, p. 597).

Time to nearest second	Estimated size of fish making simple flight				Estimated size of fish making compound flight			
	In western Atlantic			In W. Pacific	In western Atlantic			In W. Pacific
	Small, 15-20 cm.	Medium, 20-25 cm.	Large, 25-35 cm.	Usually 25-45 cm.	Small, 15-20 cm.	Medium, 20-25 cm.	Large, 25-35 cm.	Usually 25-45 cm.
0	..	10	2	1	1	2	..	..
1	5	5	7	14	3	..	..	3
2	2	5	1	18	1	2	..	2
3	1	4	2	7	..	2	2	6
4	1	6	2	2	..	2	1	2
5	..	3	3	2	1	3	2	3
6	..	2	1	3	3	2	1	1
7	1	1	..	1	1	2	4	3
8	..	..	1	1	..	2	4	2
9	..	..	..	1	1	2	1	4
10	..	..	..	1	1	5	2	3
11	..	..	..	..	..	3	1	1
12	..	..	..	1	..	1	1	1
13	..	..	1	1	..	..	1	4
14	..	..	..	..	..	1	..	1
15	..	..	..	..	..	1	..	..
16	..	..	..	..	..	..	1	2
17	..	..	..	..	..	..	2	..
18	..	..	..	..	..	..	..	..
19	..	..	..	..	..	..	..	1
20	..	..	..	..	..	..	..	..
21	..	..	..	..	..	..	..	..
22	..	..	..	..	..	..	..	1
23	..	..	..	..	..	..	..	1
24	..	..	..	..	..	..	..	..
25	..	..	..	..	..	..	..	..
26	..	..	..	..	..	..	..	..
27	..	..	..	..	..	..	..	..
28	..	..	..	..	..	..	..	1
Total specimens	10	36	20	53	12	30	22	42
Average time in seconds	2.2	2.4	3.3	3.2	4.5	7.2	8.6	8.8

in the equatorial current and adjacent waters the large lavender-winged flying fish, which approach 50 cm. in length, made flights which he was quite sure averaged longer than those I observed in eastern Asia. The longer flights of the larger fish are no doubt due (as Dr. Brooks pointed out by letter) to the fact that inertia, like mass, varies with the cube of the length, while air friction, like surface, varies with the square of the length. The lesser inertia but greater air resistance involved in the flight of the smaller fishes similarly explains why their flight tends to be more erratic than that of the larger ones.

As shown in Table V, the large fish in the Atlantic made flights which averaged almost exactly as long as the flights of the Pacific species observed. For simple flights (of one leap) the average time was 3.3 seconds for the large Atlantic fish and 3.2 seconds for those of the Pacific region, where the fish were large; for compound flights, 8.6 and 8.8 seconds, respectively.

The later leaps in a compound flight tended to be short, but sometimes were of considerable duration. Two timings of long third leaps in the Gulf of Mexico were of 3.2 and 3.3 seconds.

During the trip in the Gulf of Mexico and the Caribbean Sea in 1935 the impression was clearly gained that a negative, compensatory correlation exists between the duration of the first and the second leaps. A very short first hop, if continued, was typically followed by a strong taxi and a long second soar. A very long flight, if continued (often it was not), was seldom followed by a long second leap. Accurate statistics correlating the time of first and second leaps, readily obtainable, would add an interesting item to our knowledge of the flight of fishes.

VIII. SUMMARY

New observations on the flight of fishes were made chiefly in the Gulf of Mexico and the Caribbean Sea in 1935.

Previous determinations of the mode of flight by typical flying fishes are verified. *Paraxocoetus* seems to be a somewhat weaker and less expert flyer than are the Cypselurinae, and probably leaves the water more often in short, direct leaps. Power for all except incipient flights of *Paraxocoetus* and Cypselurinae is obtained by the lashing of the tail in the surface taxi. The wings remain taut after the fish wholly leaves the water.

Flying fish when frightened into the air by a ship take off almost exclusively from the windward side of the vessel, usually at right angles, when the wind is definitely from the side. They fly to both sides when the wind is from the stern. They show a tendency to turn toward the wind, especially the few that rise on the lee side of the steamer. The stimulus that determines the direction in which flying fish take off must operate under water, and is not the direction of sunlight; it may be underwater wave motion, or it may be a visual stimulus. They fly on the windward side of a ship probably either because of vibrations rebounding from that side or because flights to leeward are definitely inhibited.

Flying fish are attracted to a light at night and often injure themselves then by striking the ship. Under the light they frequently swim slowly with wings expanded.

The number of fish seen flying in the Gulf of Mexico and the Caribbean Sea in 1935 varied greatly from hour to hour. The highest count was 499 in 50 minutes. Reliable calculations of the flying fish population per square mile appear unattainable by counting those frightened into the air by a ship. The number seen per half-hour period of observation seems adequate to represent roughly the relative abundance of the fish under different conditions.

In our 447 Atlantic observations the number of successive leaps in a flight ranged from 1 to 11, with an average of 2.4, and did not vary with the size of the fish.

The 195 Atlantic flights timed varied in duration from 0 to 13 seconds, averaging 2.7 seconds for simple flights and from 0 to 17 seconds for compound flights. The larger fish flew on the average longer than the smaller ones.

UNIVERSITY OF MICHIGAN

SUPPLEMENTARY NOTE

In a recent abstract Carter and Mander (1935) confirm the view that the flight of flying fish is a glide, and state that measurements of cinematographs of fish in flight indicate the maximum speed to be 25 to 30 miles per hour (in agreement with previous estimates). They further indicate that flying fish, traversing the air at such speeds, could not travel in still air as far as they are observed to fly, and that they therefore probably make use of disturbances in

the air above the uneven surface of the water. This interpretation is at variance with my observations in Asia (Hubbs, 1933), which indicate that the characteristics of fish flight were about the same over glassy-smooth seas and over rough water.

LITERATURE CITED

- BREDER, C. M., JR. 1929. Field Observations on Flying Fishes; a Suggestion of Methods. *Zoologica*, 9: 295-312, figs. 301-305.
- 1930. On the Structural Specialization of Flying Fishes from the Standpoint of Aerodynamics. *Copeia*, No. 4: 114-121, figs. 1-3.
- 1934. The Oceanographic Vessel *Atlantis* in the West Indies. *Bull. New York Zool. Soc.*, 37: 30-39, 15 figs.
- CARTER, G. S., AND MANDER, J. A. H. 1935. The Flight of the Flying-Fish, *Exocoetus*. *Rep. Brit. Assn. Adv. Sci.*, 105: 383-384.
- FORBES, ALEXANDER. 1936. Flying Fish. *Science*, N. S., 83: 261-262.
- HUBBS, CARL L. 1918. The Flight of the California Flying Fish. *Copeia*, No. 62: 85-88.
- 1933. Observations on the Flight of Fishes, with a Statistical Study of the Flight of the Cypselurinae and Remarks on the Evolution of the Flight of Fishes. *Pap. Mich. Acad. Sci., Arts and Letters*, 17 (1932): 575-611, figs. 66-68.
- 1935. Nature's Own Seaplanes. *Smiths. Rep.*, 1933: 333-348, figs. 1-3.
- JORDAN, DAVID STARR. 1907. [The Flying Fish Problem.] *Am. Nat.*, 41: 347-348.
- LOEB, LEONARD B. 1936. The "Flight" of Flying Fish. *Science*, N. S., 83: 260-261.
- MILLS, C. A. 1936a. Source of Propulsive Power Used by Flying Fish. *Science*, N. S., 83: 80.
- 1936b. Propulsive Power Used by Flying Fish. *Ibid.*, p. 262.

IODINE AND THE PRODUCTION OF PERMANENT TADPOLES IN THE FROG (*RANA PIPPIENS*) *

JESSIE L. METCALF AND CHARLES W. CREASER

IT IS well known that tadpoles in which the thyroid has been destroyed never transform into frogs unless given iodine or thyroxin (Allen, 1918; Hoskins, 1919). Recently we have produced some permanent tadpoles, without operative procedure, as an unexpected result in other experiments. This work is now being checked as a major interest, and many very suggestive points have arisen which cannot be studied until more specimens are available. It seems, however, that it may be possible to devise a very fine physiological test for iodine when present in exceedingly small quantities.

These tadpoles were the product of fertilization of eggs obtained in experiments on ovulation induction. Hence the source of water from the beginning of growth is known. The eggs were stripped on March 28, 1935. The larvae were fed on lettuce and common white bread. The water for the period up to June 1 was the tap water of the City of Detroit. At that time, when they were about 20 mm. long, they were taken to a village on Lake Huron and kept in water from an artesian well until August 10. From August 10 to September 15 they were kept in water from a small brook and were then returned to water of the Detroit system in the laboratory. On March 20, 1936, two specimens of the group were still alive. They had been at the maximum size for their species (84 mm.) for approximately two months. They should have transformed, at the latest, seven months before, but they still gave no signs of becoming frogs. They had developed hind legs, but the front legs, although in one specimen they were seen through the skin fully developed, had not emerged and the tails were undiminished. In

* This investigation has been aided by the government agency NYA and the alumni research fund of the biology department of Wayne University.

a word, they had not transformed into frogs. The condition of the lungs and other organs was not known.

That the difficulty lies in the lack of sufficient iodine is evidenced by the experiment of giving a high iodine environment to certain individuals from the same lot. These soon transformed, as shown by the development of fore limbs and the absorption of tails.

It is evident, therefore, that tadpoles may be kept alive and raised in an environment so low in iodine that they remain tadpoles. Whether (1) an effect is produced in early stages which enables so little thyroid to be formed that the later iodine content in amounts normal to the region fails to metamorphose them, or whether (2) there is too little iodine in the tap water of Detroit to metamorphose them even with a normal thyroid development cannot be determined until we have more specimens.

It is of great interest to know that Detroit city tap water is too low in iodine to cause transformation of these tadpoles. Certainly the iodine content of our local natural frog ponds cannot be much higher. Chemists seem to have no easy or reliable test for iodine at these concentrations, and no careful test of the iodine content of the Detroit city tap water has been reported, according to the chemists of the filtration plant. It would seem desirable to devise, if possible, a method not involving considerable evaporation for the determination for iodine at these concentrations. Tadpoles of a closely related species raised in distilled water to which had been added 0.000,001 m. iodine will transform, as has been shown by Lynn and Brambell (1935). In distilled water (with food very low in iodine) they will not transform. It would seem that the iodine threshold lies below this figure (0.000,001 m.); with more specimens we hope to determine the limits for this frog (*Rana pipiens*). It may be possible thus to devise a very delicate physiological test for iodine based on the transformation of tadpoles. Similar tests of remarkable sensitivity for certain hormones are well known.

With the well-established correlation between low iodine content and goiter incidence, as shown by McClendon and Williams (1923) and Kimball (1920), and the well-established beneficial effect of sea foods and iodized salt, as indicated by McClure (1935), it would seem that consideration should be given again to this low iodine content in water of the Detroit system. It might at least be advisable to raise the content to that of the drinking water in ocean-

port cities such as Baltimore, where goiter incidence is much lower and where the iodine content is known to be sufficient for metamorphosis of a closely related species of frog, a fact discovered by Lynn and Brambell (1935).

In any event we again have a very interesting experiment showing how we gain control of the frog by a careful understanding of its biology. We can cause an egg to be laid, inseminate it artificially, raise the tadpole, and make it remain a tadpole by giving it an environment low in iodine. In a similar fashion it is likely that, if we could understand the biology of man, we might control some of his social and economic problems.

WAYNE UNIVERSITY
DETROIT, MICHIGAN

LITERATURE CITED

- ALLEN, B. M. 1918. The Results of Thyroid Removal in the Larvae of *Rana pipiens*. Journ. Exper. Zool., 24: 499-519.
- HOSKINS, E. R. AND M. M. 1919. Growth and Development of the Amphibia as Effected by Thyroidectomy. Journ. Exper. Zool., 29: 1-70.
- KIMBALL, O. P. 1920. The Efficiency and Safety of the Prevention of Goitre: Results of a Survey in Michigan. Journ. Am. Med. Assn., 91: 454-460.
- LYNN, W. G., AND BRAMBELL, C. 1935. Effects of Lack of Iodine upon Amphibian Growth and Metamorphosis. Anatomical Record, Vol. 64, Supplement 1, Abstract No. 40.
- McCLENDON, J. F., AND WILLIAMS, A. 1923. Simple Goitre as a Result of Iodine Deficiency. Journ. Am. Med. Assn., 80: 600-601.
- McCLURE, R. D. 1935. Goitre Prophylaxis with Iodized Salt. Science, 82: 370-371.

BIOLOGY OF THE BOXWOOD LEAF MINER
(*MONARTHROPALPUS BUXI* LABOU)
IN MICHIGAN *

DONALD T. RIES

THE cultivation of boxwood in Michigan as an ornamental plant is not a common practice because of the difficulty in carrying the plants through the severe winters. In the vicinity of Detroit, however, the writer found several plantings. A number of reports were received during the fall of 1931 that many of the larger bushes looked sickly and that the leaves showed signs of bronzing and withering. Upon investigation they were found to be infested with the boxwood leaf miner (*Monarthropalpus buxi* Labou). The adult of this insect is a small mosquito-like fly, reddish yellow and very frail. It belongs to the order Diptera and the family Cecidomyiidae. It is a European insect and was brought into this country from France and Holland sometime prior to 1910. It was in that year that Dr. E. P. Felt first reported its occurrence in this country on material sent to him from Rhode Island.

The injury to the host plant is done by the larvae feeding on the tissues of the leaves, which causes the foliage to wither and drop off prematurely. This premature dropping leaves the plant undernourished, scraggly, and very unsightly (Pl. LXIX, Fig. 2), as compared with the dense green foliage of healthy bushes. Instead of retaining their leaves over a period of several years, the heavily infested plants rarely keep them more than slightly over a year, and the foliage is thin and ragged.

In the vicinity of Detroit the adults (Pl. LXIX, Fig. 1) of the boxwood leaf miner begin to emerge from the leaves sometime during the latter part of May and continue to emerge over a period of ten to twelve days. The two sharp cephalic horns enable the semi-

* This work was carried on while the author was associated with the Cranbrook Institute of Science, Bloomfield Hills, Michigan. The paper was read before the Michigan Academy in February, 1934.

active pupae to break through the thin lower epidermis of the leaf, and soon afterward the adults emerge. They push out until a little more than half the body is projecting. The adults crowd the body forward within the pupal skin and split it lengthwise on the thorax, releasing the head, then the antennae and the wings, after which the legs are released and, finally, the abdomen. The entire process takes four to five minutes. The wings are entirely expanded and the adults are able to walk or fly about three to four minutes after releasing themselves.

Matings were observed taking place on the plant within a short time after emergence. During oviposition, which occurs very soon after mating, the female thrusts the curved, needle-like ovipositor through the lower surface of the leaf. The chitinous ovipositor has a shallow slit on the dorsal side through which the egg passes. During oviposition the caudal portion of the abdomen is drawn up under the rest of the body. After insertion of the ovipositor the abdomen is moved from side to side, as if to enlarge the cavity in which the egg is to be deposited. Oviposition requires from five to eight and one-half minutes, according to observations made by the writer. No opening is distinguishable after the ovipositor is withdrawn. The eggs may be seen easily, however, especially on the new growth, by holding the leaves up to the light.

The eggs (Pl. LXIX, Fig. 3), when taken from the leaves, are distinctly flattened and nearly circular. They have a tough membranous covering that is without sculpturing or markings, and are very pliable. They are whitish to transparent. Eggs dissected from the ovaries of females were more or less oval and averaged about 0.28 mm. in length and about 0.15 mm. in width. Just how many were laid by a single female was not accurately determined. Ovarian examinations showed from 45 to 70 present, while oviposition records of nearly 200 females in laboratory cages showed an average of 33 per female.

The eggs hatch into the curled first instar larvae (Pl. LXVII, Fig. 4) about two weeks after deposition. These larvae remain curled in a semicircle in the cavities in which the eggs were laid. They are white and measure about 0.85 mm. in length. The first instar larva possesses a conical head segment on which are found the small papilla-like antennae, and extremely small, almost indistinguishable, apparently unchitinized mouth parts; a distinct neck

segment, three thoracic segments, and nine abdominal segments. The surface is smooth, except for a few minute tubercles forming a band at the intersegmental furrows. The writer was able to distinguish only six pairs of spiracles, on the first six abdominal segments. The first instar lasts about four weeks.

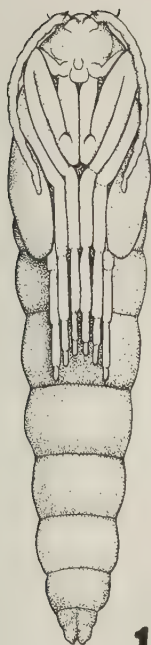
The second instar larva assumes a spindle shape and averages about 1.6 mm. in length. It is widest in the thoracic region and slightly compressed dorsoventrally. Spiracles are easily distinguished on the prothorax and the first abdominal segments. The body is distinctly tuberculate on the dorsum and sides, with a band of small tubercles forming the cephalic edge of the ventral sclerites. There are four stout sharp setae on each thoracic and on the first to eighth abdominal segments, one below each spiracle and a second slightly lower on the side. A pair of small pointed appendages are found on the caudal margin of the last abdominal segment. This instar begins mining in the leaves and causes the "blisters" to form on the lower surface. The second instar lasts eight to ten weeks.

In the third instar the tubercles become more pronounced and the typical forked "breastbone" appears. This instar is formed sometime during September, depending upon the length of the preceding instar. The larvae average about 2.0 mm. in length. The stout, spinelike setae on the abdominal segments become more pronounced and considerably darker. The winter is passed in this stage.

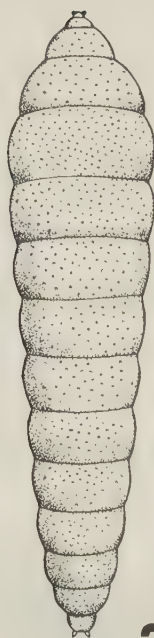
The yellowish fourth instar larvae (Pl. LXVII, Fig. 2) are found during the latter part of March or the first part of April. They average about 2.5 mm. in length. The tuberculation is very distinct in this stage. The head is conical and chitinized with small single-segmented antennae. The mouth parts (Pl. LXVII, Figs. 3, 5) are made up of an upper lobe (labrum), a chitinized conical mandibular lobe on each side, with a triangular maxillary lobe below each, and a median triangular lower lobe (labium). A sharp, needle-like projection is found on the distal end of the maxillary and labial lobes. There is a distinct neck segment immediately behind the head. On the prothorax are found the prothoracic spiracles laterally, while the "breastbone" occurs on the venter. Upon dissection it is found that the "breastbone" extends caudad to the caudal margin of the prothorax as a chitinized process, where it broadens into a T-shaped bar. The abdominal appendages are very distinct and seem to help

PLATES LXVII-LXIX

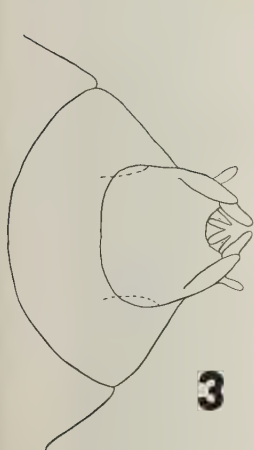
PLATE LXVII



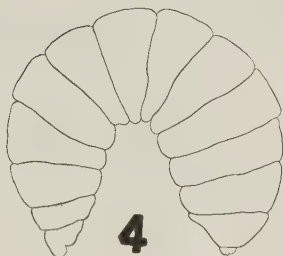
1



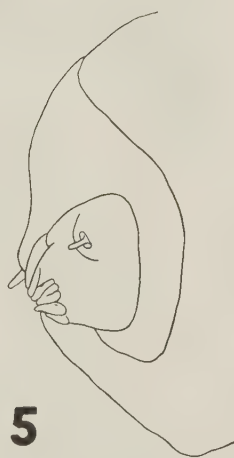
2



3



4



5

- FIG. 1. Ventral view of pupa
 FIG. 2. Dorsal view of fourth instar larva
 FIG. 3. Dorsal view of head, showing arrangement of mouth parts
 FIG. 4. Lateral view of first instar larva
 FIG. 5. Cephalolateral view of head of mature larva

PLATE LXVIII

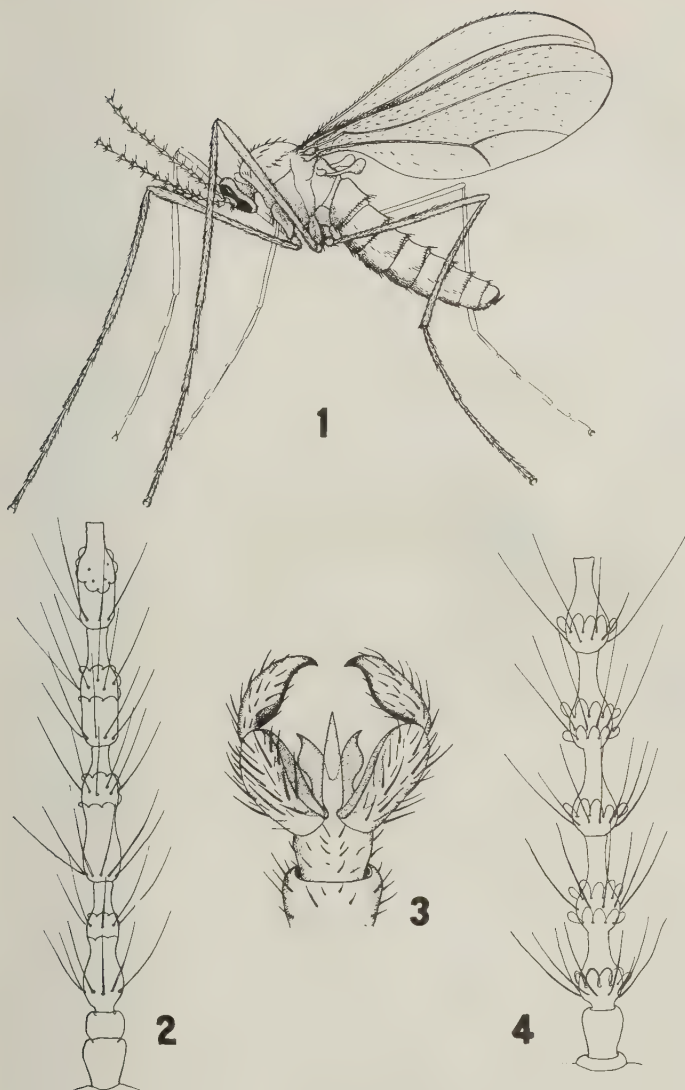


FIG. 1. Adult female *Monarthropalpus buzi*

FIG. 2. Basal portion of antenna of female

FIG. 3. Male genitalia

FIG. 4. Basal portion of male antenna

PLATE LXIX



FIG. 1. Leaves showing adults and pupae emerging

FIG. 2. Infested leaves showing blisters caused by larvae (upper row); uninfested leaves (lower row)

FIG. 3. Eggs of *M. buxi* greatly enlarged

STUDIES ON THE FEMALE REPRODUCTIVE
SYSTEM OF THE PRAIRIE DOG,
CYNOMYS LEUCURUS

II. NORMAL CYCLIC PHENOMENA OF THE
OVARIAN FOLLICLES *

ALFRED H. STOCKARD

INTRODUCTION

IN PREVIOUS papers the author has outlined the reproductive and seasonal activities and the gross morphology of the female reproductive system of the prairie dog (1929, 1930, 1934). This paper embodies a description of certain normal cyclic phenomena in the ovary.

The investigation was conducted on a series of 192 reproductive tracts from animals collected in Wyoming between March 27 and July 4 in 1925, 1927, and 1928. General descriptions of the material and the technique of its preparation have already been published (1934). Complete serial sections were made of one ovary from each female taken in 1925 and 1927 and of each female taken after parturition in 1928. After histological preparation the ovaries were studied under a Spencer binocular microscope with 15 $\times$ planoscopic oculars and a 1.8 mm. N.A. 1.25 hom. immersion objective. Measurements were made with an ocular micrometer calibrated against a stage micrometer. Cytological drawings were made with the aid of the equipment listed above and a Spencer camera lucida, yielding a magnification of 2,250 diameters. Photographs were made on "Eastman Wratten M. Plates" in a perpendicular bellows camera box above a Leitz research microscope equipped with achromatic lenses. A Spencer "cold-nose" microscope lamp provided the illumination.

* Contribution from the Department of Zoölogy, University of Michigan.

PRESENT STATUS OF THE PROBLEM

De Graaf (1672), Von Baer (1827), Valentin (1838), Bischoff (1842 to 1854), and Pflüger (1863) made important studies on the structure of the ovary, but were handicapped by inadequate material, primitive technical methods, and a lack of related information. The work of Waldeyer (1870) ushered in a series of modern investigations on the structure and the functions of the ovary.

The development of the ovary must be followed in order to determine the relationships of its many parts. Certain structures which appear during foetal or early postnatal life become vestigial or obliterated before sexual maturity is attained, and others undergo complete change of form, position, or relation during development. During the period from 1900 to 1908 Winiwarter and Sainmont published a series of memoirs on their studies of the ovary of the cat. No other adequate study on the morphogenesis of the ovary of a mammal has been reported. B. M. Allen (1904) and Kingsbury (1913) reported studies which agreed with some results and disagreed with others obtained by Winiwarter and Sainmont. It was thought that a detailed investigation of the structure and development of the ovary in some one mammal might harmonize the findings of these authors in the cat, the pig, and the rabbit and provide a firmer morphological basis for additional investigations.

GENERAL STRUCTURE OF THE MAMMALIAN OVARY

The ovary of the prairie dog, in common with the ovaries of other mammals, presents two major zones, cortex and medulla (Pl. LXXI, Fig. 1). The cortex is a broad, firm peripheral region, interrupted at the hilus and surrounded by a dense tunica ovarii, which is covered by a simple ovarian epithelium. The cortex is made up of Graafian follicles embedded in a stroma of loose connective tissue. The medulla is a central, spongy mass devoid of follicles, but indistinctly delimited from the cortex. It is composed of loose connective tissue, many large blood vessels, nerves, muscle cells, and occasional medullary cords and tubular remains of the rete ovarii. Medullary and rete tissues continue through the hilus into the mesovarium. Embedded in the hilus and mesovarium are epoöphoral vesicles of various sizes and numbers.

Though there is lack of agreement as to the derivation of the

several parts of the mammalian ovary, the following outline, based on the work of B. M. Allen (1904), appears to incorporate the opinions of most recent investigators: (1) The ovarian epithelium gives rise to ova,¹ follicular epithelium, medullary cords, and rete ovarii; (2) The stroma (of mesenchymal origin) differentiates into tunica ovarii, loose connective tissue, thecae folliculi, interstitial cells, and muscle cells; (3) Vascular tissues, nerves, and the epoöphoron invade the ovary from the mesovarium.

GENERAL CYCLIC PHENOMENA

During the life cycle of the prairie dog the curve of physiological activity of the reproductive organs rises rapidly to a crest at puberty and recedes slowly to senility. Seasonal and oestrous cyclic changes are superimposed on the life-cyclic changes. Many of these changes are sufficiently marked to obscure the life-cyclic changes, but the latter overshadow other less conspicuous ones. In ovaries from wild animals of unknown ages it is often impossible to distinguish between life-cyclic, seasonal, and oestrous changes.

The presence of life-cyclic changes is well known in man, and presumably they occur in all mammals, but in none have these changes been followed through a complete life period. Until these changes have been studied over the normal life of some mammal they will continue to be disturbing factors in any morphological investigation of the ovary.

OVARIAN EPITHELIUM

The ovarian epithelium in the adult prairie dog is a simple cuboidal layer covering the tunica ovarii (Pl. LXX, Fig. 1). Its cells have indistinct membranes and relatively large nuclei. They are packed closely together and are high over concave portions, but more widely spaced and low over convex portions of the organ. The nuclei usually appear spheroidal in the high cells and oval in the low ones. On careful examination they are found to be cut into lobules by deep fissures. The chromatin is in the form of an irregular network or in granules, and two or three indistinct karyosomes are present. Mitotic figures are extremely rare. Occasionally cells with

¹ Strictly, "ovum" is the cell after discharge of the second polar body and before the fusion of the male and the female pronuclei. For brevity, the term is here applied to all recognizably potential ova.

large, clear nuclei are seen in the ovarian epithelium. Such cells resemble those described by Hargitt (1930) in the rat as young ova. The possibility that they are young ova is not denied, but they also have the appearance of epithelial cells approaching mitosis.

In extremely rare instances single cells, folds, or columns of cells extend into the tunica ovarii, though retaining their connection with the epithelium (Pl. LXX, Fig. 2). These intrusions usually occur in the area adjacent to the hilus and where the epithelial cells are most crowded. The cells are similar in appearance to the ordinary ovarian epithelial cells, and seem to be forced from the surface rather than to be actively invading the tunica. Occasionally small clumps of epithelial cells are found in the tunica, where its fibers run at an angle to the surface, and numerous cysts of similar cells lie deeper in the ovary (Pl. LXX, Figs. 2-3). The destiny of the cysts is subject to three conjectures, namely, that they become primordial ova, anovular follicles, or both ova and granulosa cells.

In the absence of intermediate stages between the cysts of ovarian epithelial cells and the youngest ova, there is only indirect proof from certain changes within the ovary that the ovarian epithelium in the prairie dog gives rise to ova during sexual maturity. Formation of new ova does not occur during the period covered by this study, and mitosis in the epithelium is not frequent enough to support a cycle of invasion during this period. Furthermore, no ova are recognizable in the epithelium, and intermediate stages between epithelial cells within the ovary and ova are lacking.

OVA

During the period studied all recognizable ova were located in the cortex of the ovary. They are cytologically distinct from the cells of the ovarian epithelium and from the cells of the clumps and cysts beneath it (Pl. LXX, Figs. 1, 3). No satisfactory evidence of a transition from the undifferentiated cells in a cluster to granulosa cells and ova has been discovered. However, the rate of degeneration of ova in the ovary, the small number of ova often encountered, and the absence of invasions of differentiated ova from the epithelium support an inference that they must come from this source, which is in agreement with the belief of Papanicolaou (1924) that ova, once within the stroma of the ovary, pass rapidly through their growth stages to maturity or to degeneration.

Polyovular follicles and nests containing 5 to 15 or more young ova, with few or no follicle cells, are frequently present (Pl. LXXI, Fig. 2). This suggests that one, many, or all of the cells in a cluster may transform into ova and few or none into granulosa cells. However, the preponderance of monovular follicles indicates that typically only one cell of a cluster becomes an ovum. The occasional presence of ova of different sizes in a single follicle may result from a difference in the time of initiation of growth or in the rate of differentiation.

During their period of growth ova pass through the usual sequence of synchronous changes, including the formation of a zona pellucida and its transformation into a zona radiata; increase in volume of the cytosome and in density of the yolk flakes; development of yolk nuclei; growth, later shrinkage, and final disintegration of the nucleus at meiosis; transformation of the chromatin through spireme stages to tetrads, and their separation into dyads; increase in the basichromatin content, subsequent loss of the basichromatin, and final dissolution of the nucleolus.

All recognizable ova in the ovary are enclosed in capsules of granulosa cells. They are approximately 25 micra in diameter when first identified (Pl. LXX, Fig. 3; Pl. LXXI, Fig. 3) and approximately 92 micra when mature (Pl. LXXII, Figs. 3-4). The ovum is surrounded by a distinct membrane. A zone of hyaloplasm encloses the nucleus, and peripherally many yolk granules are found which become larger and more numerous as growth progresses. Small numbers of refractive, acidophilic spherules enclosed in indefinite vacuoles appear in the periphery of ova of diameters of 35 micra and increase in numbers to 100 or more in the larger ova (Pl. LXX, Fig. 3; Pl. LXXII, Fig. 4).

The nucleus of the young ovum is a centrally located sphere 12 to 15 micra in diameter, and is bounded by a distinct nuclear membrane (Pl. LXXI, Fig. 3). Its chromatin is arranged in irregular loops radiating from one or two chromatin nucleoli. The nucleus assumes an eccentric position and increases in size with the ovum until near maturity, when it attains its maximum diameter of 30 micra (Pl. LXXII, Fig. 2), after which it shrinks to approximately 12 micra. Its chromatin becomes detached from the nucleoli, takes on a reticulate appearance, and later is collected into approximately 24 basichromatic spherules. As maturity approaches, the nucleoli

disappear and the spherules of chromatin condense into short, thick masses. Because of their clumping it has been impossible to count these masses accurately. Their number, however, is no less than 20 and no greater than 24. Since this agrees with the count of tetrads on the first maturation spindles, the masses are interpreted as representing early tetrads, and the changes leading up to them as synaptic changes.

Occasionally large ova with first and many with second meiotic division spindles are found. The follicles of all ova observed to be in meiosis, except a single one in first meiotic division, had not reached full size and were in an atretic condition. Meiotic divisions in all immature ova of the period studied are abortive, and the ova are destined to degenerate simultaneously with their follicles. A discussion of the problem of atresia will be presented in a later paper.

A thin hyaline zona pellucida appears around the ovum of approximately 35 micra in diameter, and becomes thicker and more conspicuous around larger ova (Pl. LXX, Fig. 5). As the periovular space becomes progressively wider with the growth of the ovum the zona pellucida is drawn out in the form of an open net, the zona radiata, whose radiating fibers connect the ovum and the granulosa cells (Pl. LXXI, Figs. 4-6).

There are cyclic variations in the rates of origin of ova and in the relative numbers produced, and also of atretic and normal follicles of the various ages. Nests of primordial ova and young ova in follicles are present in ovaries taken throughout the spring and the early summer. The number of young ova is generally greater early in the season, though there are exceptions to this, probably due to individual age differences — the older animals producing fewer young ova and the younger ones producing them over a longer seasonal period. The transformation of epithelial cells into young ova probably occurs before hibernation is broken, since the younger ova are most abundant in early spring and since such transformation has not been observed in animals taken at any time during their active season.

FOLLICLES

Typical follicles may be classed as normal or atretic. Normal follicles are found in various stages of development in the same ovary. Normal or atypical follicles of any size may become atretic

and undergo involution. Only the developmental history of normal follicles is described here.

Normal follicles change greatly in size and in shape during development. In a younger follicle only a single layer of thin cells with flattened nuclei surrounds the ovum (Pl. LXX, Fig. 3). As a result of rapid division the cells become crowded, first into cuboid and then into columnar form (Pl. LXX, Fig. 5; Pl. LXXI, Fig. 4). By continued growth the follicular epithelium retreats from the ovum, leaving a wide periovular space, into which some follicular cells migrate, forming an inner layer (Pl. LXXI, Figs. 4-5). The outer layer retreats from the inner one, leaving an interzonal space. The inner layer in turn retreats from the ovum, leaving another periovular space, across which processes from the cells of the two layers pass to the zona pellucida. Upon further retreat of the granulosa cells, the zona pellucida is drawn out to form a zona radiata (Pl. LXXI, Figs. 4-6).

Cells from both the inner and the outer layers are seemingly crowded into the interzone, where they usually take up irregular positions (Pl. LXXI, Fig. 6). In many follicles these interzonal cells are oriented in rosettes around acidophilic Call-Exner bodies, which are usually replaced later by vesicular spheres (Pl. LXX, Fig. 4; Pl. LXXI, Fig. 6). Spaces appear between the masses of interzonal cells and coalesce into a single antrum, of semilunar form in the immature follicle but of spherical form in the mature one (Pl. LXXII, Figs. 1, 3). In fixed material the contents of the antrum appear granular and contain occasional remnants of the Call-Exner bodies. At the time of the appearance of the antrum the wall of the follicle is approximately six cells in thickness. When the follicle reaches maturity the cumulus oöphorus is spherical and has a wall approximately eight cells in thickness. It separates later from the follicular wall, and is discharged with the ovum at ovulation.

During growth the young follicle acquires a capsule consisting of a theca interna and a theca externa (Pl. LXXII, Fig. 5). The granulosa cells of the outer sphere assume a columnar form and become regularly aligned against the follicular capsule, this condition being maintained throughout the life of the follicle. The cells of the inner sphere are at first pear-shaped, with narrow ends directed away from the ovum, but later they become columnar. They persist in the mature follicle as the corona radiata, attached to the ovum by long

cytoplasmic processes (Pl. LXXII, Fig. 4). The interzonal cells retain an irregular arrangement, or regain it after the destruction of the Call-Exner bodies, and pass from a reticulate to a polygonal form (Pl. LXXII, Fig. 6). Cytoplasmic strands connect all adjacent cells. Processes extend into the antrum from the cells nearest it and to the zona radiata from its neighboring cells.

Follicular growth is accomplished by an increase in the number and the size of the granulosa cells and by the enlargement of the antrum. Mitotic figures are common in the granulosa cells of all immature follicles, but are entirely absent from those of mature ones, and the cells, which are small and thin in the young follicle, become very large as the follicle matures. Their nuclei become correspondingly larger, are usually eccentric in position, and contain from two to six very conspicuous karyosomes and numerous chromatin granules. A paranuclear mass of fibrils is present and occasionally vacuoles are discernible. During the formation of the antrum the cells appear to contain much fluid, suggesting secretory activity. Vascular tissue does not invade the granulosa portion of the follicle.

A follicular capsule, consisting of thin cells with flat nuclei closely applied to the granulosa layer, is present. It is first recognizable when the follicle cells have become cuboid and persists with only a slight increase in thickness until the follicle matures (Pl. LXX, Fig. 5; Pl. LXXII, Fig. 5). The theca interna arises shortly after the follicular cells become cuboid, as a single layer of flattened stromal cells. By frequent mitosis it eventually attains a thickness of approximately six cells (Pl. LXXII, Fig. 5). Some of its cells become polygonal and increase greatly in size, until in the mature follicle they are larger than the granulosa cells. Others remain thin and appear as supporting tissue interwoven among the polygonal cells. The polygonal cells have large, eccentric, oval nuclei, with two or three large karyosomes and an indefinite paranuclear structure. The theca externa develops gradually as the follicles grow and is composed of stromal cells against which the follicle expands (Pl. LXXII, Figs. 3, 5). Mitosis is rare in this layer, and little change occurs in the structure of its cells during development. As the follicle expands it comes in contact with the tunica ovarii from which numerous blood vessels pass into the thecal layer.

The number of available ova is probably the factor which limits

the production of typical follicles. Nests of young ova without follicles appear, but their fate is unknown. Anovular follicles appear (Pl. LXX, Fig. 3), and it is doubtful whether they produce or acquire ova later. Typical follicles follow a definite course in their growth, leading either to atresia or to ovulation. The time and the rate of their formation, the speed with which they develop, and the time at which atresia overtakes some of them determine the relative numbers of follicles of the several sizes in an ovary. Mitosis, hypertrophy, and secretory activity constitute the cytological changes. The lack of knowledge of the age of each animal studied and poorly understood cyclic conditions dependent on age militate against clear-cut interpretations of both classes of changes.

Mature follicles (Pl. LXXII, Fig. 3) are present only at oestrus and have been found only in animals that have a copulation plug in the reproductive canal. Ovulation had occurred in all animals taken after oestrus, and only immature follicles were found in those taken before oestrus. Immature follicles of varying ages were also present in all animals taken before implantation of embryos, and in many animals taken later. Sample counts in all ovaries showed the relative number of very large but immature follicles to be highest before oestrus, to drop to a low number at mid-pregnancy, and to rise again at the period of parturition. After this no change was apparent. The number of large immature follicles, both normal and atretic, was lowest during pregnancy, indicating that fewer follicles pass mid-size at this period. The total absence of mature follicles after oestrus indicates that follicles do not mature after corpora lutea are established.

Middle-sized follicles were numerous in all animals examined, though their number is reduced after the beginning of pregnancy. Atresia is very common in follicles of this size during pregnancy, and during this period the total number of both normal and atretic middle-sized follicles is very high. It is to be inferred that younger follicles reach middle size, at which level they are held by atresia. Younger follicles are numerous throughout the entire active season of the animal and are rarely atretic. In general, the younger follicles predominate early in the season. Their numbers vary, however, in different individuals of the same catch, due possibly to some such factor as variation in age.

Cyclic structural changes also occur in the follicle cells. There

is a wave of mitotic activity in early spring which affects both granulosa and theca cells of all follicles. The mitotic rate remains high during oestrus and early pregnancy, but drops to a low level at mid-pregnancy, where it remains throughout the rest of the active season. During the period from oestrus to implantation there are a marked increase in the size of the theca interna cells and a more intense reaction of the chromatin to stains in all cells of the larger follicles. Secretory activity is inferred from the glandular appearance of these hypertrophied cells.

HISTORY AND DISCUSSION

The germinal nature of the ovarian epithelium in mammals was recognized by Pflüger (1863), who described the ingrowth of cellular cords from it. Valentin (1838) had previously described the origin of ovarian follicles from cords present within the ovary, and Waldeyer (1870) later reported the origin of both granulosa cells and ova from these cords. More recent investigators are generally agreed that a developmental relationship exists between the ovarian epithelium and the ova and granulosa cells.

The nature of the cells composing the ovarian epithelium, however, is still an unsettled question. Waldeyer (1870) believed the epithelium to be made up originally of identical somatic cells, which, after leaving it, might differentiate into several types. Nussbaum (1880) advanced the theory that it was made up of somatic cells, among which were found germ cells derived by early segregation. Lanc-Clayton (1905) and Swezy (1929) maintained that it was composed entirely of germ cells. Kingery (1917) held that its cells were all potential germ cells, although of somatic nature. Hargitt (1930) contended that germ cells were not segregated early, but that the ovarian epithelium and, consequently, all its derivatives, such as medullary cords, late foetal follicles, juvenile proliferations, and follicles and ova of the adult were transformed peritoneal cells. He says (1925) that "germ cell origin is a problem of cellular differentiation, and not of early segregation. . . ." His belief follows that of Winthart (1900), that a complete degeneration of the earliest recognizable germ cells occurs in the immature ovary and that the idea of a continuity of germ cells is thereby disproved.

Recent investigations favor the theory that the ovarian epithelium of embryos contains potential germ cells. Those who hold that

new ova continue to form during the period of sexual maturity claim that germ cells are also present in the ovarian epithelium of adults. The view that the epithelium is made up of germ cells of an early segregation in addition to somatic cells is also tenable.

Heys (1931) outlines the recent views regarding the origin and the fate of the germ cells of the ovarian epithelium as follows: (1) that the germ cells are not segregated early, but arise entirely by differentiation of somatic cells; (2) that they are segregated early and locate in the gonad, but degenerate before sexual maturity; (3) that they are segregated early, locate in the gonad, and produce definitive germ cells, but that their numbers are augmented periodically by a proliferation, possibly of somatic origin; and (4) that they are segregated early, multiply by mitosis only, and are not augmented or replaced by somatic cells.

Though most recent investigators agree that mammalian ova are derived from the ovarian epithelium, the time and the manner of their derivation and their subsequent history are variously interpreted. Some hold that they invade the ovarian cortex in the young animal only, while others believe that repeated invasions, periodic or continuous, occur throughout life. Many believe the invasion to be by clusters, each cluster differentiating into an ovum and its granulosa cells. Others think that the ovum and its granulosa cells arise by separate invasions. Still others hold that only ova come from the epithelium, granulosa cells arising from the stroma.

According to Waldeyer (1870), the ovum and the granulosa cells are cytogenetically identical; those epithelial cells which stop dividing become ova, whereas those that continue to divide become granulosa cells. Allen (1923) found no group invasions from the epithelium in the adult mouse. He described a displacement of individual cells into the stroma of the ovary after mitosis in the epithelium. Swezy (1929) described a simultaneous origin of ova and follicular cells from the germinal epithelium and regarded them all as sister cells. Follicular cells were distinguished while the ovum was still in the germinal epithelium, and the two types of cell were found to sink into the stroma together. Evans and Swezy (1930) described invasions by one or more seemingly identical epithelial cells without any mitosis immediately preceding the invasion. They held that both ova and granulosa cells came from the invading clumps.

Hargitt (1930b) stated that in the rat new ova are produced in the adult ovary by two methods: (1) Single cells of the germinal epithelium enlarge *in situ* and become surrounded by smaller neighboring cells. The group then moves from its surface position into the tunica albuginea and becomes a young follicle. (2) A number of germinal epithelial cells round up into a mass, and without enlargement of any cells the entire group moves into the albuginea, where one or more cells may grow and transform into ova, whereas others remain small and form follicle cells. League and Hartman (1925) believe that granulosa cells are produced by the epithelium and that they seek out and surround the ova in the stroma of the ovary.

Van Beneden (1880) reported the origin of the ovum and the granulosa cells from a syncytial invasion. Lane-Claypon (1905) held that ova are derived early from the epithelium, serve for a time as interstitial cells, and then change to functional ova. She and McIlroy (1910) described the ovum and its granulosa cells as being derived from the epithelium at different times and held that certain of the cells undergo a partial transformation into ova and then revert to granulosa cells. Jenkinson (1913) did not believe that germ cells in mammals were ever located in the ovarian epithelium but thought that they originated in a subepithelial zone.

The observations on the prairie dog here reported support the view that new ova arise from the ovarian epithelium during sexual maturity. The author considers it unlikely that ova arise from somatic cells, and therefore believes that the ovarian epithelium contains germ cells or indifferent cells of an early segregation. The structural similarity of all cells in the ovarian epithelium in turn supports the idea that it is composed entirely of germ cells or, at least, of germinative tissue capable of producing both functional germ cells and accessory structures. Judgment on its true nature must await the discovery of more reliable cytological criteria for identifying germ cells and improvement in transplantation and tissue culture methods.

The evidence from the study of the prairie dog indicates that groups of similar epithelial cells invade the cortex of the ovary before the annual spring period of activity of the animal and that each group usually differentiates into an ovum and its granulosa cells. None, several, or all such cells may form ova, resulting in an-ovular or polyovular follicles or afollicular nests of ova, respectively.

This interpretation agrees with the reports of Waldeyer (1870), Evans and Swezy (1930), and Hargitt (1930b).

After differentiation the young ova go through a period of rapid growth. The process of yolk formation has been studied in ova of various animals, but homologies are uncertain and interpretations are varied. The presence in the ova of the prairie dog, during their period of growth, of numerous cytoplasmic granules surrounded by clear zones of hyaloplasm suggests that these granules are centers of yolk formation.

Interpretations of the homologies of the egg membranes are not in harmony. Maximow (1931) believed that the zona pellucida was in contact with the protoplasm of the egg and that its radial structure was due to protoplasmic processes traversing it from the granulosa cells to the ovum. He described the outer layer of the zona pellucida as being reticular and attached to the cells of the corona radiata. He believed it to have a dual origin, being derived from both the ovum and the granulosa cells. Arey (1934) states that there is an inner vitelline membrane secreted by the ovum, and that the zona pellucida surrounds the vitelline membrane. Wilson (1925) is of the opinion that the zona pellucida is produced by the ovum, but Corner (1928) thinks that it is produced by follicular cells. Tur (1912), on evidence from polyovular follicles, from follicles without coronae radiata, and from atretic follicles, concluded that the zona pellucida is a product of the ovum. His interpretation is supported by abundant, similar evidence from the ovaries of the prairie dog. In this animal the zona pellucida appears to be a secretion from the ovum laid down outside the vitelline membrane and possibly transformed into a zona radiata by traction of the cells of the corona radiata, which adhere to its outer surface.

Synaptic changes during ovogenesis have been described in many animals. Balfour (1878) observed nuclear changes in the ova of young mammals. Similar observations by later workers were followed by a systematic investigation of ovogenesis in mammals by Winiwarter (1901), who described synaptic changes in the ova of rabbits up to eighteen days of age and took these as a criterion for the identification of germ cells. Winiwarter and Sainmont (1908) reported that in the cat all definitive ova have completed synapsis at four months *post partum* and that no subsequent synaptic changes occur. Pratt and Long (1917) declared that synaptic changes in

the rat ceased at four days *post partum*. Kingery (1917) described indistinct synaptic changes in ovarian epithelial cells in the mouse, but did not consider synapsis necessary in germ-cell history. Cowperthwaite (1925) opposed this view, declaring, as did Winiwarter, that synapsis is a criterion for identification of germ cells, and that its absence in the adult white rat bespoke the absence of ovogenesis. Swezy (1929) interpreted the nuclear changes in young ova of adult rats as modified synapsis. Chromatic activity throughout the period of growth in ova of the prairie dog terminates in a haploid number of chromatic masses. This activity is interpreted as modified synapsis.

Foulis (1876) described the transformation of the early, flat, follicle cells to the cuboid and columnar granulosa cells, their multiplication to form a multilayered body, and a final disintegration of some of the deeper cells with the accompanying formation of a lentiform antrum filled with liquor folliculi. He noted the absence of capillaries in the granulosa layer, and described the vascularization of the theca interna and the hypertrophy of its cells as the follicle approached maturity. The membrana propria surrounding the granulosa layer was described by Balfour (1878), and the follicular capsule of attenuated connective tissue cells associated with the membrana propria was described by Paladino (1888). Call and Exner (1875) described the formation of rosettes of granulosa cells about acidophilic bodies. These Call-Exner bodies may originate through a secretory activity of granulosa cells, in the form either of a liquor folliculi or of a protective secretion analogous to the substance of the zona pellucida about some foreign body as a center. Honoré (1900) attributed the follicular fluid to cell degeneration or to secretion. Lane-Claypon (1905) ascribed all fluid formation to karyolysis of the granulosa cells. Follicular growth in the prairie dog is similar to that in other forms. Foulis and Lane-Claypon have apparently confused karyolysis of the granulosa cells of atretic follicles with the normal production of follicular fluid. The glandular appearance of the granulosa cells and the presence of great numbers of Call-Exner bodies in normal follicles which possess an antrum indicate that cells are not destroyed in the process of producing either follicular fluid or Call-Exner bodies.

Lutein and interstitial tissues have a close genetic relationship to ovarian follicles, though the full extent of these relationships is

not known. Lutein tissue is clearly of dual origin, being formed from granulosa cells and theca interna cells. The origin of interstitial tissue has been variously interpreted. It has been traced to the stroma, to theca interna cells of atretic follicles, to granulosa cells of anovular follicles, and by Lane-Clayton (1905) to functional ova at an intermediate period in their life. In the prairie dog the tissue appears to be of a heterogeneous nature. Shortly after oestrus, cells of the medullary cords, the theca externa, the theca interna, the stroma, the lymphoid tissue, and the epoöphoron hypertrophy and present a marked glandular appearance. Three interpretations may be placed on these structures: (1) Theca-lutein and granulosa-lutein tissues may be physiologically distinct and of independent origin, the first being derived from the stroma and the second from the ovarian epithelium. Likewise, the several types of interstitial cells may be distinct in function and in origin, but synchronous in hypertrophy. (2) All lutein tissues, and likewise all interstitial tissues, may be genetically and functionally identical, differing only in location. (3) They may be passive structures which hypertrophy in response to stimuli from secretions produced by other tissues in the ovary. It is not possible to determine from a morphological study of the adult ovary which of these interpretations is correct.

SUMMARY AND CONCLUSIONS

1. Cytological and histological studies were made on the ovaries of 192 white-tailed prairie dogs taken during their active season, from March 27 to July 4.

2. Oestrous, seasonal, and life-cyclic changes are superimposed in the ovary.

3. During the period covered by this study the ovarian epithelium is a superficial, mitotically quiescent, simple cuboid layer of apparently identical cells. Single cells and small groups of cells projecting from the epithelium into the tunica ovarii, and isolated groups in the tunica ovarii, seldom occur. Groups of identical epithelial cells in the superficial cortex beneath the tunica ovarii are relatively common.

4. All recognizable ova during this period are located in capsules of granulosa cells in the ovarian cortex. The high rate of degeneration of ova and the limited number of young ova suggest that new

ova are formed in the adult. The complete absence of mitosis in ova implies that they originate by a transformation of other cells. The structural similarity of the granulosa cells to the cells of the epithelial groups within the ovary indicates that these groups are the source of follicular cells as well as of the ova. The absence of transitional stages between epithelial cells and ova indicates that transformation does not occur during the period covered in this study.

5. Usually one ovum is found in a capsule of granulosa cells. Polyovular follicles, anovular follicles, and afollicular nests of ova occur rarely. This indicates that typically one cell of an epithelial group transforms into an ovum, whereas the others become granulosa cells. The follicular capsule, the theca interna, and the theca externa originate from the stroma.

6. After invasion, the follicles rapidly complete their life cycle, which terminates in atresia or in ovulation.

7. All ova possess a distinct cell membrane and at an early age produce an elastic zona pellucida, which is later transformed by traction of its granulosa cells into a zona radiata.

8. During growth the ovum increases from a diameter of 25 micra to one of 90, while its nucleus increases from a diameter of 12 micra to one of 30, and becomes eccentrically located in older ova.

9. The nucleus contains a basophilic nucleolus which becomes acidophilic in older ova, and numerous granules, strands, and karyosomes of chromatin, which aggregate into a haploid number of tetrads as maturity approaches.

10. Granulosa cells of growing follicles undergo frequent mitosis, pass from squamous to cuboid or columnar form, and increase greatly in size. In arrangement they pass from a single-layered to a multi-layered sphere, in which the intermediate cells often assume a rosette pattern about Call-Exner bodies. In older follicles they develop a paranuclear structure and become secretory. Interstitial spaces coalesce to form an antrum about 900 micra in diameter when mature. The cumulus oöphorus is discharged into the antrum as a sphere. In older follicles the nuclei of the granulosa cells develop many large karyosomes.

11. The theca interna increases by mitosis in growing follicles and passes from a body of a single layer in thickness to one of 5 or 6 layers. Its cells change from a squamous to a polygonal form and in older follicles exceed the granulosa cells in size.

12. As the follicle enlarges, the theca externa increases in thickness, largely by the addition of stromal cells, to a small extent by cell division.

13. The theca interna becomes progressively more vascular in growing follicles. Blood vessels do not enter the granulosa tissue.

14. Young follicles are most numerous early in the season. Older normal follicles are most numerous before implantation and least so at mid-pregnancy. Mature follicles are present only at oestrus. The rate of follicular growth is at its peak early in the season.

15. Atresia is not prevalent before oestrus, but is common during pregnancy.

UNIVERSITY OF MICHIGAN

LITERATURE CITED

1. ALLEN, B. M. 1904. The Embryonic Development of the Ovary and Testis of the Mammalia. *Am. Journ. Anat.*, 3: 89-155.
2. ALLEN, EDGAR. 1923. Ovogenesis during Sexual Maturity. *Am. Journ. Anat.*, 31: 439-481.
3. AREY, LESLIE B. 1934. Developmental Anatomy. Third Edition. W. B. Saunders Co., Philadelphia.
4. BAER, CARL E. VON. 1827. *De ovi mammalium et hominis. Genesi Epistola.* Leipsiae.
5. BALFOUR, F. M. 1878. On the Structure and Development of the Vertebrate Ovary. *Quart. Journ. Microsc. Sci., N. S.*, 18: 383-438.
6. BISCHOFF, T. L. W. 1842. *Entwicklungsgeschichte der Säugethiere und des Menschen.* L. Voss. Leipzig.
7. CALL, E. L., UND EXNER, SIGMUND. 1875. Zur Kenntniss des Graafschen Follikels und des Corpus luteum beim Kaninchen. *Wien, K. Akad. d. Wissensch. Math.-Naturw. Sitzber. Cl. 71 (Abt. 3)*: 321-328.
8. CORNER, G. W. 1928. Cytology of the Ovum, Ovary and Fallopian Tube. *In Special Cytology*, edited by E. V. Cowdry, 2: 1111-1150. P. B. Hoeber, New York.
9. COWPERTHWAIT, MARIAN H. 1925. Observations on Pre- and Post-Pubertal Oögenesis in the White Rat, *Mus norvegicus albinus*. *Am. Journ. Anat.*, 36: 69-90.
10. DE GRAAF, R. 1672. *De mulierum organis generationi inservientibus tractus novus.* 8°, Lugundi Batavorum [Leyden] ex Officina Hackiana.
11. FOULIS, JAMES. 1876. On the Development of the Ova and Structure of the Ovary in Man and Other Mammalia. *Quart. Journ. Microsc. Sci.*, 16: 190-220.

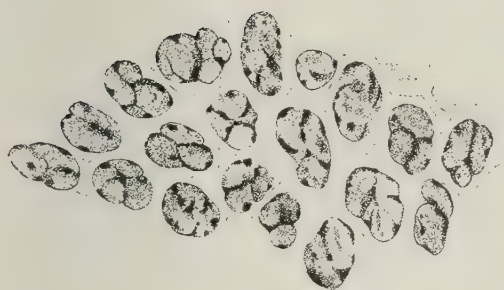
12. EVANS, H. M., AND SWEZY, O. 1930. The Human Ovarian Germ Cells. *Journ. Morphol.*, 49: 543-577.
13. HARGITT, G. T. 1925. The Formation of the Sex Glands and Germ Cells of Mammals. I. The Origin of the Germ Cells in the Albino Rat. *Journ. Morphol.*, 40: 517-558.
14. — 1930a. The Formation of the Sex Glands and Germ Cells of Mammals. III. The History of the Female Germ Cells in the Albino Rat to the Time of Sexual Maturity. *Ibid.*, 49: 277-331.
15. — 1930b. The Formation of the Sex Glands and Germ Cells of Mammals. IV. Continuous Origin and Degeneration of Germ Cells in the Female Albino Rat. *Ibid.*, 49: 333-353.
16. HEYS, FLORENCE. 1931. The Problem of the Origin of Germ Cells. *Quart. Rev. Biol.*, 6: 1-41.
17. HONORÉ, C. 1900. Recherches sur l'ovaire du lapin. *Archiv. de Biol.*, 16: 537-600.
18. JENKINSON, J. W. 1913. *Vertebrate Embryology*. Oxford.
19. KINGERY, H. M. 1917. Oögenesis in the White Mouse. *Journ. Morphol.*, 30: 261-316.
20. KINGSBURY, B. F. 1913. The Morphogenesis of the Mammalian Ovary (*Felis domestica*). *Am. Journ. Anat.*, 16: 59-96.
21. LANE-CLAYPON, J. E. 1905. On the Origin and Life History of the Interstitial Cells in the Ovary in the Rabbit. *Proc. Roy. Soc. London*, Ser. B, 77: 32-57.
22. LEAGUE, BESSIE, AND HARTMAN, C. G. 1925. Anovular Graafian Follicles in Mammalian Ovaries. *Anat. Rec.*, 30: 1-14.
23. MAXIMOW, A. A. 1931. *Text-Book of Histology*. W. B. Saunders Co., Philadelphia.
24. McILROY, A. LOUISE. 1910. The Development of the Germ Cells in the Mammalian Ovary, with Special Reference to the Early Phases of Maturation. *Proc. Roy. Soc. Edinb.*, 31: 151-178.
25. NUSSBAUM, M. 1880. Zur Differenzierung des Geschlechts im Thierreich. *Archiv mikr. Anat.*, 18: 1-121.
26. PALADINO, G. 1888. La Destruction et le renouvellement continu du parenchyme ovarique des mammifères. *Arch. ital. de Biol.*, 9: 176-202.
27. PAPANICOLAOU, G. N. 1924. Ovogenesis during Sexual Maturity as Elucidated by Experimental Methods. *Soc. Exper. Biol. and Med.*, 21: 393-396.
28. PFLÜGER, E. F. W. 1863. Über die Eierstöcke der Säugethiere und des Menschen. W. Engelmann. Leipzig.
29. PRATT, B. H., AND LONG, J. A. 1917. The Period of Synapsis in the Egg of the White Rat, *Mus norvegicus albinus*. *Journ. Morphol.*, 29: 441-460.
30. STOCKARD, A. H. 1929. Observations on Reproduction in the White-Tailed Prairie-Dog (*Cynomys leucurus*). *Journ. Mammal.*, 10: 209-212.

31. ——— 1930. Observations on the Seasonal Activities of the White-Tailed Prairie-Dog, *Cynomys leucurus*. Pap. Mich. Acad. Sci., Arts and Letters, 11 (1929): 471-479.
32. ——— 1935 Studies on the Female Reproductive System of the Prairie Dog, *Cynomys leucurus*. I. Gross Morphology. Pap. Mich. Acad. Sci., Arts and Letters, 20 (1934): 725-735.
33. SWEZY, O. 1929. The Ovarian Chromosome Cycle in a Mixed Rat Strain. Journ. Morphol., 48: 445-474.
34. TUR, J. 1912. Sur l'origine de la zone pellucide des œufs des mammifères. Compt. rend. Soc. d. Biol., 72: 336-337.
35. VALENTIN, G. 1838. Über die Entwicklung der Follikel in dem Eierstock der Säugethiere. Archiv f. Anat. und Physiol., pp. 526-535.
36. VAN BENEDEN, E. 1880. Contribution à la connaissance de l'ovaire des mammifères. Archiv. de Biol., 1: 475-550.
37. WALDEYER, W. 1870. Eierstock und Ei. Leipzig
38. WILSON, E. B. 1925. The Cell. The Macmillan Co., New York.
39. WINIWARTER, H. VON. 1901. Recherches sur l'ovogenèse et l'organogenèse de l'ovaire des mammifères (lapin et homme). Archiv. de Biol., 17: 32-197.
40. ——— ET SAINMONT, G. 1908. Nouvelles recherches sur l'ovogenèse et l'organogenèse de l'ovaire des mammifères (chat). *Ibid.*, 24: 1-276.

EXPLANATION OF PLATE LXX

- FIG. 1. Ovarian epithelium, superficial view, showing the indistinct cell boundaries, the large, lobulated nuclei, and the uniform structure of the cells
- FIG. 2. Section of the ovarian epithelium and the tunica ovarii, showing the cuboid structure of the epithelium and a cluster of epithelial cells invading the tunica. Another group of epithelial cells with lobulated nuclei is shown deeper in the tunica
- FIG. 3. A typical young ovum in its follicle of flattened granulosa cells. The cell membrane, perinuclear zone of hyaloplasm, and strands of chromatin centering on the nucleolus are shown. Beside the follicle is an anovular cyst of epithelial cells, with lobulated nuclei
- FIG. 4. A cluster of granulosa cells surrounding a Call-Exner body
- FIG. 5. Portion of an early ovum and follicle, showing the early zona pellucida, the follicular capsule, and the theca interna

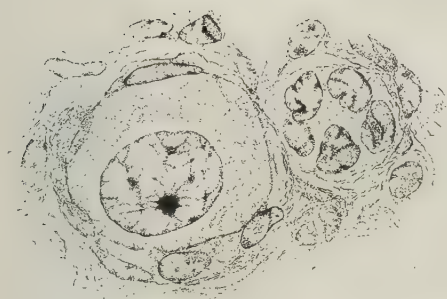
PLATE LXX



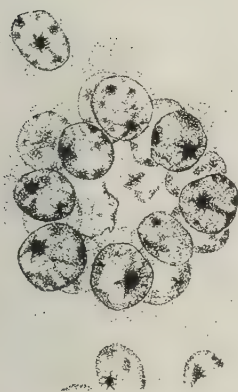
1



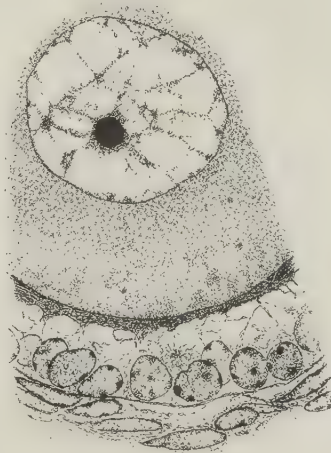
2



3



4

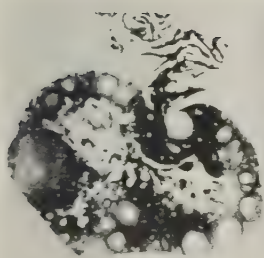


5

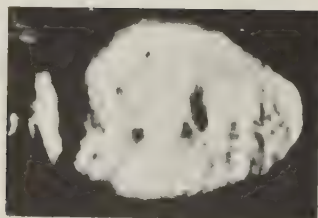
EXPLANATION OF PLATE LXXI

- FIG. 1. Sagittal section of ovary, showing cortex bearing numerous follicles and a corpus luteum, vascular medulla, hilus, and mesovarium
- FIG. 2. A nest of young ova in the cortex, with no follicle cells near them
- FIG. 3. A young ovum surrounded by flattened granulosa cells. Its nucleus is large, and the chromatin is in the form of heavy strands centering on the nucleolus. Numerous yolk granules and occasional spherules enclosed in vacuoles are shown in the cytosome
- FIGS. 4-5. Ova in follicles whose granulosa cells have formed inner and outer spheres and are transforming the zonae pellucidae into zonae radiatae
- FIG. 6. An older ovum and follicle. The theca externa and the membrana propria, and the inner and outer spheres of granulosa cells and the interzonal cells clustered about Call-Exner bodies are shown. Numerous mitotic figures are seen in the granulosa cells

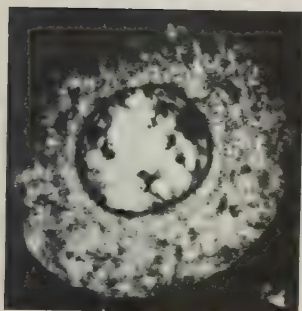
PLATE LXXI



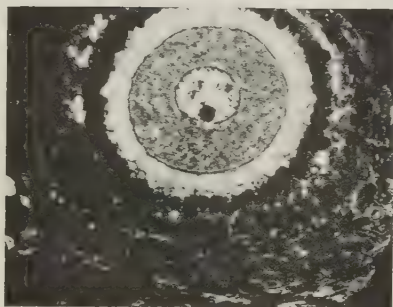
1



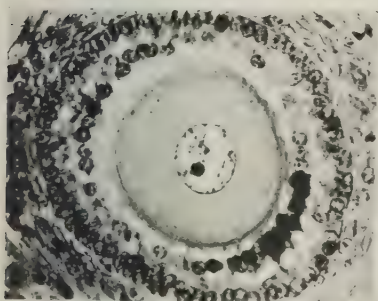
2



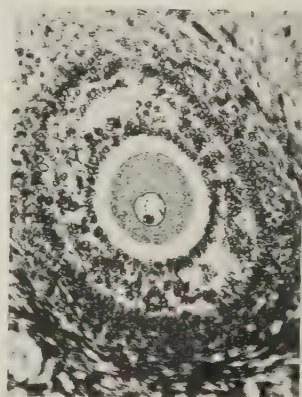
3



4



5

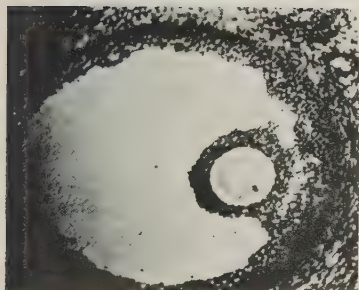


6

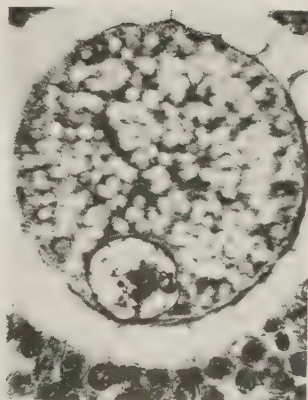
EXPLANATION OF PLATE LXXII

- FIG. 1. A large, immature follicle possessing a lenticular antrum, into which the cumulus oöphorus, with its ovum, is being discharged
- FIG. 2. Details of a large, immature ovum. The nucleus is shown at its maximum size and with its chromatin material in the form of basichromatic spherules
- FIG. 3. A mature follicle containing a spherical antrum, in which the cumulus oöphorus is free-floating
- FIG. 4. Ovum and corona radiata of a mature follicle. Paranuclear structures are apparent in the granulosa cells and numerous yolk granules and yolk nuclei in vacuoles are seen in the ovum
- FIG. 5. Details of the theca externa, the theca interna, the membrana propria, and the peripheral granulosa cells of a follicle nearing maturity
- FIG. 6. Details of the interzonal granulosa cells of a follicle nearing maturity

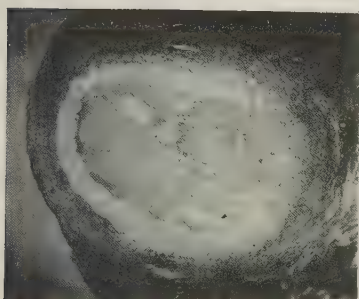
PLATE LXXII



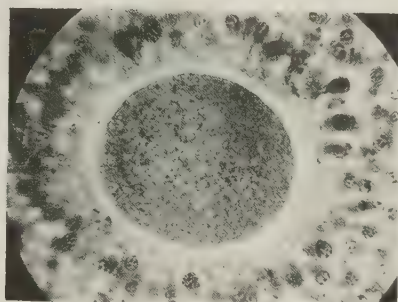
1



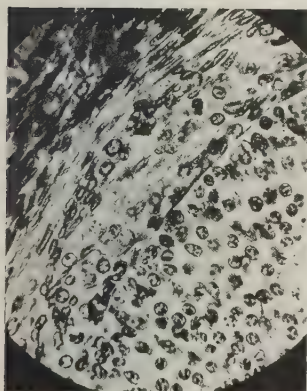
2



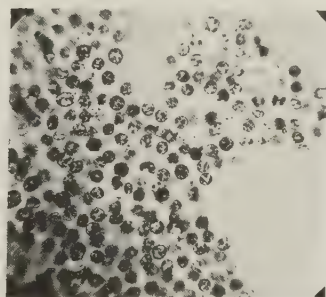
3



4



5



6

THE AGE, GROWTH, AND SEX RATIO OF
THE LAKE SUPERIOR LONGJAW, *LEUCICHTHYS ZENITHICUS* (JORDAN
AND EVERMANN) *

JOHN VAN OOSTEN

I. INTRODUCTION

SIX species of *Leucichthys* occur in Lake Superior. They are: *artedi*, *kiyi*, *hoyi*, *nigripinnis*, *reighardi*, and *zenithicus*. *Zenithicus*, the short-jawed chub, also known among the commercial fishermen as the longjaw or the cisco, may be distinguished from its close relatives by the following group of characters, as determined by Koelz (1929): In side view the body is elliptical; the mandible is short, immaculate or faintly pigmented, and usually included within the maxillary; the snout truncated in side view is relatively long; the maxillary is comparatively long and more or less pigmented; the head has relatively little depth; the number of gill rakers on the first branchial arch usually varies from 39 to 43, and the number of lateral-line scales usually ranges from 74 to 84. In life *zenithicus* is a silvery color, with its dorsal surface varying from a dark blue-green to a pale pea green.

At the present time *zenithicus* is the only large chub that is common enough in Lake Superior to be taken in commercial quantities, although, according to Koelz (p. 384), this species "does not support, nor is it certain that it ever has maintained, a fishing industry." In abundance it ranks second to *artedi*, the lake herring. *Zenithicus* occurs all along the shores of Lake Superior at depths of from 11 to 100 fathoms, where it is taken in gill nets. It spawns in late November and early December, probably at depths of from 20 to 40 fathoms, on clay bottom. Specimens 150 millimeters long (standard length) usually show maturing sex organs, and virtually all those 200 millimeters or more in length are sexually mature. The largest

* Published with the permission of the United States Commissioner of Fisheries.

specimen observed by Koelz measured 332 millimeters in standard length, and very few individuals taken by him had attained a length greater than 300 millimeters. *Zenithicus*, like the other chubs, is smoked for the market. It has not been propagated artificially, but it has received some protection under the various laws that regulate the catch of chubs in Lake Superior. Minnesota, Wisconsin, and Michigan provide a closed season; the Province of Ontario provides a minimum size limit below which chubs may not be marketed; and all these governments regulate the minimum size of gill-net mesh that may be used for the capture of chubs.

Nothing is known concerning the food habits, spawning, migration, age, growth, and actual abundance of *zenithicus* in Lake Superior, and very little has been published on the life history of this species in other lakes. Bajkov (1930) gave some brief life-history notes on this species of Lake Winnipeg. He presented a graph showing the rate of growth as determined from a study of some fifty individuals. No other data on the age and growth of *L. zenithicus* have been published.

II. MATERIALS AND METHODS

The present study is based on 589 Lake Superior longjaws identified by Dr. Walter Koelz and collected by him on July 17, 1922, 20 miles NE by E from Duluth, Minnesota, with 2½-inch mesh gill nets set on a sandy bottom in 30-40 fathoms of water. Length and weight measurements, which were all based on preserved specimens, were not corrected for shrinkage of the fish in formalin and alcohol. Standard length measurements were recorded in millimeters and weights in ounces. Age determinations, weight and length measurements, both actual and computed lengths, were made by Mr. E. J. McClure, formerly of the United States Bureau of Fisheries, but his readings were checked by me. Ages expressed by roman numerals represent, in accordance with current practice, the number of annuli found on the scales. Thus, a IV-year fish represents one taken in its fifth year of life. For greater detail concerning the methods employed in a study of age and growth based on scales the reader is referred to one of my earlier papers (1929). All the specimens examined were maturing or were sexually mature. I am greatly indebted to Dr. Ralph Hile for valuable assistance rendered in the preparation of the tables and in reviewing the manuscript.

III. AGE COMPOSITION, LENGTH FREQUENCIES,
MAXIMUM LENGTH AND WEIGHT

In Table I the fish in the sample have been divided into age groups and according to the year class to which they belong, with the individuals of each age group arranged according to length. The number of individuals in each age group and the percentage of that

TABLE I

FREQUENCY DISTRIBUTION OF THE LAKE SUPERIOR LONGJAW ACCORDING TO STANDARD LENGTH IN MM., AGE GROUP (ROMAN NUMERALS), AND YEAR CLASS (CALENDAR YEARS), WITH SEXES COMBINED

Length in mm.	Age group and year class							Total number
	IV 1918	V 1917	VI 1916	VII 1915	VIII 1914	IX 1913	X 1912	
180-184	1	..	...	...	..	..	..	1
185-189	..	..	...	...	..	..	..	...
190-194	1	..	1	...	..	..	..	2
195-199	2	..	...	...	..	..	..	2
200-204	1	2	...	...	..	..	..	3
205-209	..	..	...	...	..	..	..	...
210-214	..	2	...	...	..	..	..	2
215-219	..	2	...	...	..	..	..	2
220-224	..	6	2	...	..	..	..	8
225-229	..	5	1	...	..	..	..	6
230-234	..	8	7	...	..	..	..	15
235-239	..	3	30	5	..	..	..	38
240-244	..	3	54	10	..	..	..	67
245-249	..	3	42	21	1	..	..	67
250-254	..	1	34	64	7	..	..	106
255-259	..	..	10	52	8	..	..	70
260-264	..	..	10	52	13	..	..	75
265-269	..	..	4	24	23	..	..	51
270-274	..	..	1	9	23	2	1	36
275-279	..	..	...	2	10	1	..	13
280-284	..	..	...	3	6	2	..	11
285-289	..	..	...	1	3	3	..	7
290-294	..	..	...	...	..	1	..	1
295-299	..	..	...	...	1	..	1	2
300-304	..	..	...	...	..	4	..	4
Total number	5	35	196	243	95	13	2	589
Percentage in sample	0.8	5.9	33.3	41.3	16.1	2.2	0.3	

number in the entire collection are shown at the bottom of the table. The column at the right gives the number of fish of each size group. The table reveals that no fish taken were younger than 4 years or older than 11 and that age groups IV and X were poorly represented. Age group VII predominated in the sample, comprising 41.3 per cent of the catch. The bulk (90.7 per cent) of the sample was composed of individuals that belonged to age groups VI, VII, and VIII.

In length the bulk (93.2 per cent) of the sample ranged between 230 millimeters (total length 11 inches) and 284 millimeters (total length 13.6 inches), with the mode (17.9 per cent) at 252 millimeters (total length 12 inches). It may be noted that length is a poor index of age, since fish of the same length may belong to as many as three or four different age groups. The smallest specimen in the sample was a female of age group IV; it measured 182 millimeters in length (total length 8.7 inches) and weighed 2.25 ounces. The largest specimen in the sample measured 304 millimeters in length (total length 14.5 inches) and weighed 11 ounces; it was a female of age group IX. The heaviest male, which was also the longest, weighed 9.75 ounces, measured 289 millimeters in length (total length 13.8 inches), and belonged to age group IX. The largest specimen recorded by Koelz measured 332 millimeters in length (total length 15.9 inches). The oldest male and female were in their eleventh year of life.

IV. GROWTH IN LENGTH AND WEIGHT

Table II, in which are presented the actual average length and weight for each sex of each age group and of the entire sample, indicates that on the average the females were slightly longer and weighed more than the males of corresponding age groups. The males of the sample averaged 251 millimeters in length (total length 12 inches) and 5.6 ounces in weight, the females 255 millimeters (total length 12.2 inches) and 6.1 ounces, and both sexes together 254 millimeters in length (total length 12.1 inches) and 5.9 ounces in weight. That no significant differences in growth rate, expressed in terms of length, occur between the sexes is brought out more clearly in Table III, which shows the average computed lengths reached at the end of each year of life by the males and females of three well-represented age groups. In all further discussions of growth rates based on lengths the males and the females may be

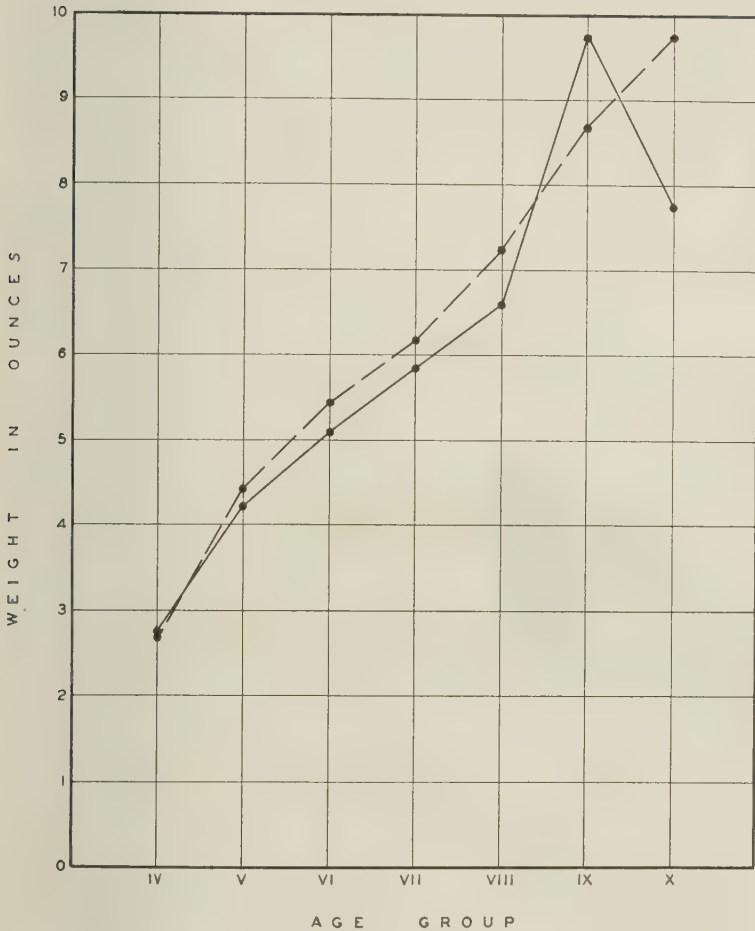


FIG. 22. Average weight in ounces of the males (—) and the females (---) of age groups IV–X of the Lake Superior longjaw. Data from Table II

considered together. The curves of Figure 22, plotted from the weights of the males and females of Table II, reveal that the females are consistently heavier than the males at all ages. The few inconsistencies that occur may be explained on the basis of a paucity of specimens.

TABLE II

AVERAGE LENGTH AND WEIGHT AND AVERAGE WEIGHT INCREMENTS IN OUNCES FOR EACH SEX AND FOR THE SEXES COMBINED OF EACH AGE GROUP OF THE LAKE SUPERIOR LONGJAW

Total lengths were computed from relationship, standard length = 0.824 total length.

Sex	Character	Age group							
		IV	V	VI	VII	VIII	IX	X	IV-X
Male	Standard length (mm.)	192	229	244	256	264	289	272	251
	Total length (inches)	9.2	10.9	11.7	12.2	12.6	13.8	13.0	12.0
	Weight (grams)	78	120	145	166	187	276	220	159
	Weight (ounces)	2.75	4.22	5.10	5.85	6.60	9.75	7.75	5.6
	Weight increments (ounces)	....	1.47	0.88	0.75	0.75	.....	.....	.....
	Number of specimens	2	9	101	117	34	1	1	265
Female . .	Standard length (mm.)	193	229	247	258	270	289	295	255
	Total length (inches)	9.2	10.9	11.8	12.3	12.9	13.8	14.1	12.2
	Weight (grams)	77	126	154	175	205	246	276	173
	Weight (ounces)	2.67	4.43	5.44	6.18	7.24	8.69	9.75	6.1
	Weight increments (ounces)	....	1.76	1.01	0.74	1.06	1.45	.....	.....
	Number of specimens	3	26	95	126	61	12	1	324
Male and female	Standard length (mm.)	193	229	245	257	268	289	284	254
	Total length (inches)	9.2	10.9	11.7	12.3	12.8	13.8	13.6	12.1
	Weight (ounces)	2.70	4.38	5.26	6.02	7.01	8.77	8.75	5.9
	Weight increments (ounces)	....	1.68	0.88	0.76	0.99	1.76	.....	.....

TABLE III

COMPARATIVE GROWTH RATE IN STANDARD LENGTH OF THE TWO SEXES OF AN AGE GROUP OF THE LAKE SUPERIOR LONGJAW

Age group	No. of specimens	Sex	Length at capture	Calculated length at end of year							
				1	2	3	4	5	6	7	8
VI	101	Male	244	80	106	136	168	196	222	...	...
VI	95	Female	247	80	108	138	170	197	224	...	...
VII	117	Male	256	81	108	135	162	188	211	234	...
VII	126	Female	258	80	107	135	163	189	214	236	...
VIII	34	Male	264	80	106	132	156	178	203	224	244
VIII	61	Female	270	81	106	133	159	182	205	229	249

Table IV shows for the sexes combined the computed length attained by each age group (and year class) at the end of each year of life. Grand averages of length and increments in length are given

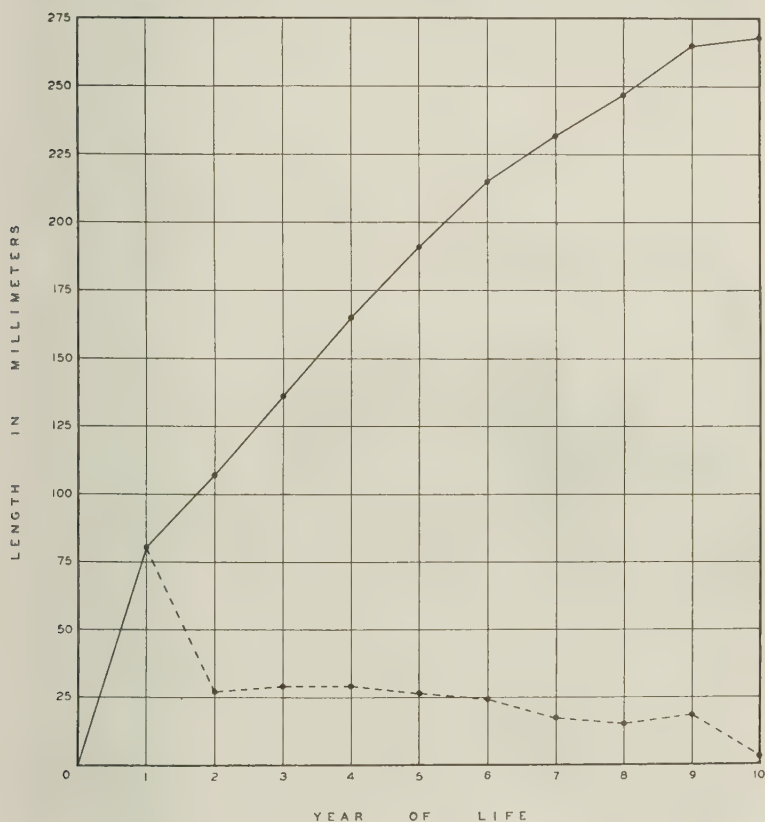


FIG. 23. Growth curves of Lake Superior longjaw. Average calculated standard length at end of each year of life —; average calculated increment in length for each year of life - - -. Curves based on grand averages of Table IV

at the bottom of the table. The curves of Figure 23 are based on these grand averages. The data of the various age groups suggest that the well-represented year classes and age groups grew at approximately the same rate. This similarity in growth history is, perhaps,

not surprising in view of the fact that throughout its entire life *zenithicus* inhabits the deeper waters of Lake Superior, where the seasonal temperatures vary little from year to year. Figure 23 and the grand averages of the table show that the longjaw grows very rapidly during the first year of life, when its growth increment is on the average about three times as large as that during any one of the

TABLE IV

CALCULATED STANDARD LENGTH IN MM. ATTAINED BY VARIOUS AGE GROUPS (AND YEAR CLASSES) OF THE LAKE SUPERIOR LONGJAW AT THE END OF EACH YEAR OF LIFE, WITH SEXES COMBINED

Year class	Age group	No. of specimens	Standard length at capture (mm.)	Average calculated length attained at end of year									
				1	2	3	4	5	6	7	8	9	10
1918	IV	5	193	78	108	145	175	...	...	...	...	...	...
1917	V	35	229	82	112	146	178	207	...	...	...	...	...
1916	VI	196	245	80	107	137	169	196	223	...	...	...	...
1915	VII	243	257	80	107	135	163	189	213	235	...	...	...
1914	VIII	95	268	81	106	133	158	181	204	227	247	...	...
1913	IX	13	289	83	110	134	164	182	206	227	248	268	...
1912	X	2	284	68	94	116	145	165	188	204	228	248	268
Grand average calculated length.....				80	107	136	165	191	215	232	247	265	268
Grand average growth increment.....				80	27	29	29	26	24	17	15	18	3
Number of specimens.....				589	589	589	589	584	549	353	110	15	2

next five years. If the length at the end of the eighth year (247 millimeters) is taken as 100 per cent, then it may be stated that 32 per cent of the total growth in length is completed at the end of the first year of life, 43 per cent at the end of the second, 55 per cent at the end of the third, 67 per cent at the end of the fourth, 77 per cent at the end of the fifth, 87 per cent at the end of the sixth, and 94 per cent at the end of the seventh. During the years 2 to 6 inclusive growth continues at a remarkably uniform rate. In the seventh year there is another decrease in the growth increment, after which there is again maintained a uniform rate through at least the ninth year of life. Whether the sharp decrease in growth in the second year is due to the attainment of sexual maturity is not known, since the age

at maturity has not yet been determined for the longjaw of Lake Superior.

No data on growth in terms of weight are available for the first three years of life. The available figures for later years (Table II) indicate, however, that the curve of growth based on weights differs considerably from that based on lengths. From Table II it may be seen that, in comparison with the weights attained by the males (2.75 ounces) and females (2.67 ounces) during the first four years of life, those of the fifth year seem large. If the average weight of the fish (the sexes combined) in their ninth year of life (age group VIII, 7.01 ounces) is taken as 100 per cent, then it may be determined that 39 per cent of the total growth in weight is completed in the fifth year of life, 62 per cent in the sixth, 75 per cent in the seventh, and 86 per cent in the eighth year. It may be observed, then, that, although more than four years are required for the longjaw to complete 39 per cent of its growth in weight, fewer than two years are required by it to complete the same percentage of its growth in length (p. 698). Seventy-five per cent of its growth is completed in the seventh year of life when growth is expressed in terms of weight but in the fourth year when growth is expressed in terms of length.

From all these data it is evident that, in comparison with length, the percentage rate of increase in weight is small during the first years of life. During later years, however, the increase is relatively rapid. This is brought out rather clearly by the curves of Figure 24, which are based on the percentages given above. The curves show that the percentage increase in weight during the fifth and later years of life is greater than that in length. This relatively rapid increase in weight is but an expression of the fact that in bodies of nearly constant form and specific gravity the weight varies approximately as the cube of the length.

From the point of view of the commercial fisheries it would be highly profitable to protect the longjaw until its sixth year of life, when it reaches a total length of about 10.3 inches, for there is an increase in weight from the fifth to the sixth year of about 53 per cent for the males and 66 per cent for the females. From the sixth to the seventh year the increase is approximately 22 per cent for both sexes, and from the seventh to the eighth year it is about 15 per cent.

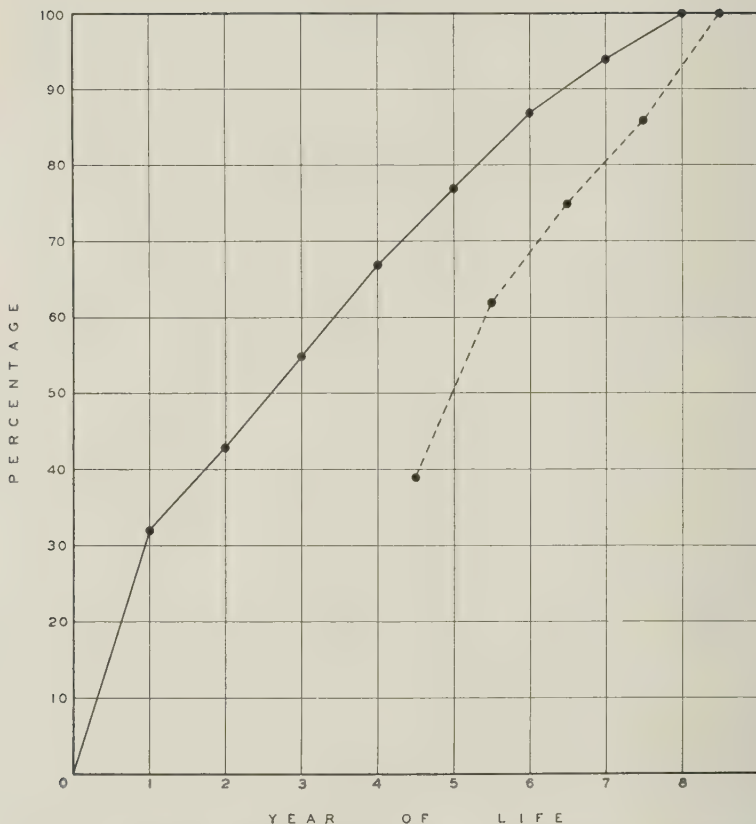


FIG. 24. Percentage of total growth in length (—) and weight (---) completed by the Lake Superior longjaw in different years of life. Data from text, pp. 698-699

V. GROWTH COMPENSATION

Compensation in growth — the tendency for individuals that grow relatively slowly in the early years of life to grow relatively rapidly during the later years — has been found in many species of fish. The subject has been reviewed by me in an earlier paper (1929). Since no information on compensation of growth in any species of chub has ever been published, it is of interest to deter-

TABLE V

GROWTH COMPENSATION. COMPUTED AVERAGE STANDARD LENGTH AND AVERAGE INCREMENT OF LENGTH FOR EACH YEAR OF LIFE FOR EACH OF FOUR SIZE GROUPS OF THE LAKE SUPERIOR LONGJAW OF AGE GROUP VII, WITH SEXES COMBINED

The size groups are based on lengths computed for the first year of life.

Size group in mm.	No. of specimens	Average computed length, in mm., for year							Length at capture	Average computed increment of length in year							
		1	2	3	4	5	6	7		1	2	3	4	5	6	7	8*
		63	94	125	154	182	210	233		63	31	31	29	28	28	23	21
Under 70 ..	33	74	102	130	159	187	211	234	254	74	28	28	29	28	24	23	22
70-79	78	85	110	136	162	188	212	234	256	85	25	26	26	26	24	22	24
80-89	79	95	118	146	172	195	217	238	258	95	23	28	26	23	22	21	22
Over 89	53								260								
Maximum difference		32	24	21	18	13	7	5	6	..	..	..	..	..	..	..	..

* An uncompleted year.

mine whether this phenomenon is present in the Lake Superior longjaw. The computed lengths of the first year of life of the fish of age group VII were divided into four size groups, as shown in Table V. The average length of the fish of each size group was then determined for each year of life. From these total lengths the average annual increments were derived. It may be seen from the table that the big yearlings were, on the average, the big fish in all succeeding years, but that the maximum differences between the lengths of the four size groups diminished each year, so that the fish became more uniform in size each successive year of age. Or, as may be seen from the increments, the smaller yearlings were, as a rule, the faster-growing fish and the larger yearlings the slower. It appears, then, that the "law of growth compensation" holds for the Lake Superior longjaw.

VI. LENGTH-WEIGHT RELATIONSHIP AND COEFFICIENT OF CONDITION

The curve of Figure 25 based on the data of Table VI has been drawn to show the relationship between the length and the weight of fish of different sizes. The black dots represent average measurements of females within single size groups, the open circles those of males. The curve has been so drawn that standard lengths in millimeters (S.L.) may be converted readily to total lengths in inches (T.L.) and vice versa, and weight in grams to weight in ounces and vice versa. The conversion of standard lengths in millimeters to total lengths in inches may be accomplished by dividing the standard length by 25.4×0.824 or 20.93. The factor 0.824 was determined empirically from the standard length—total length ratios $\left(\frac{\text{S.L.}}{\text{T.L.}}\right)$ of 112 specimens; 25.4 equals the number of millimeters in one inch. Although the females tend to be somewhat heavier than the males at corresponding lengths, a single curve expresses very well the length-weight relationship for both sexes.

As a part of the study of the length-weight relationship in the longjaw, the value of the coefficient of condition, K , was determined for individual fish by means of the well-known formula,

$$K = \frac{W \times 10^5}{L^3},$$

where W = weight in grams and L = standard length in millimeters.

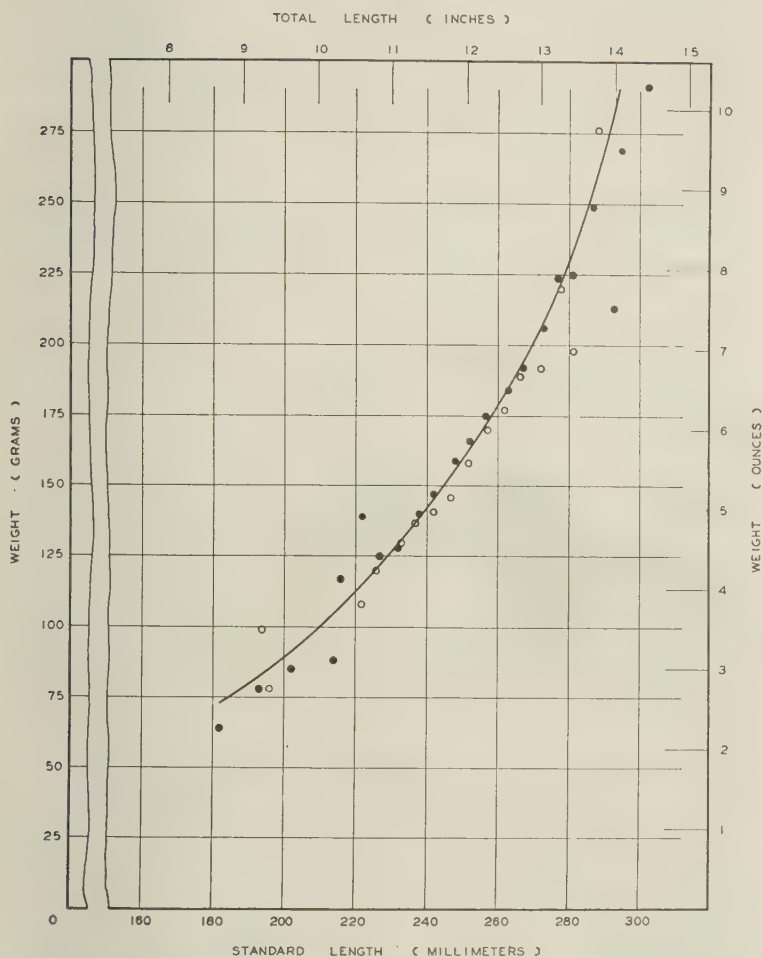


FIG. 25. Length-weight relationship of the Lake Superior longjaw. Males represented by open circles; females by black dots. Data from Table VI

An increase in the value of K represents an improvement in the condition of the fish.¹

¹ Hile (1936) gives an excellent critical discussion of the formula and the validity of its use as a means of estimating condition in fish.

TABLE VIII

COEFFICIENT OF CONDITION, K , ACCORDING TO AGE AND SIZE GROUPS
OF THE FEMALES OF THE LAKE SUPERIOR LONGJAW

The numbers of specimens are shown in parentheses.

Size group, in mm.	Age group							Average
	IV	V	VI	VII	VIII	IX	X	
180-189	1.06 (1)	....	....	....	....	....	....	1.06 (1)
190-199	1.08 (1)	....	....	....	....	....	....	1.08 (1)
200-209	1.02 (1)	1.03 (2)	....	....	....	....	....	1.03 (3)
210-219	....	1.04 (4)	....	....	....	....	....	1.04 (4)
220-229	....	1.11 (6)	1.23 (2)	....	....	....	....	1.14 (8)
230-239	....	1.03 (8)	1.04 (14)	1.10 (2)	....	....	....	1.04 (24)
240-249	....	0.99 (5)	1.05 (44)	1.06 (13)	....	....	....	1.05 (62)
250-259	....	1.04 (1)	1.02 (26)	1.03 (57)	1.12 (6)	....	....	1.03 (90)
260-269	....	....	0.96 (7)	1.02 (45)	1.05 (21)	....	....	1.02 (73)
270-279	....	....	0.88 (1)	0.96 (4)	1.06 (24)	1.03 (3)	....	1.04 (32)
280-289	....	....	....	1.02 (4)	1.04 (7)	1.01 (4)	....	1.03 (15)
290-299	....	....	....	....	1.02 (1)	0.85 (1)	1.08 (1)	0.98 (3)
300-309	....	....	....	....	....	1.06 (4)	....	1.06 (4)
Average	1.05 (3)	1.04 (26)	1.04 (94)	1.03 (125)	1.06 (59)	1.02 (12)	1.08 (1)	1.04 (320)

to decrease is much more pronounced in comparisons within single age groups (body of tables) than in comparisons with all age groups combined. The shorter fish of an age group on the whole have higher coefficients of condition than the longer fish of the same age group. Slow growth is correlated with good condition in comparisons of fish of different lengths in a single age group as well as in comparisons of fish of different ages in a single length group.

TABLE IX

CHANGE IN COEFFICIENT OF CONDITION, K , WITH LENGTH AND WITH AGE
IN THE MALES AND FEMALES OF THE LAKE SUPERIOR LONGJAW

Character of change in K	Male	Female
Average decrease of K per 1-centimeter increase in length of fish (within a single age group).....	0.014	0.017
Average decrease of K per 1-centimeter increase in length of fish (all age groups combined).....	0.008	0.008
Average increase of K per 1-year increase in age (within a 1-centimeter length group).....	0.028	0.028
Average increase of K per 1-year increase in age (all length groups combined).....	0.004	0.003

The conclusion given above, based on the examination of the data of Tables VII and VIII, was corroborated by careful mathematical analysis made for me by Dr. Hile. Details of the procedure employed cannot be presented in the space available here, but the results of the analysis are presented in summary form in Table IX. In this table it may be seen that, for each centimeter increase in the length of the fish within an age group, K decreases in value by 0.014 in the males and 0.017 in the females. These decreases are twice as large as the corresponding decreases per centimeter increase in length (0.008 in each sex), when all ages are combined. The greater change of K with increase in length in a single age group may be explained as the result of the dependence of condition on growth rate. This effect of growth rate on condition is brought out still more strongly by the comparison of changes in the value of K with increase in age within a single size group, and changes with increase in age, all length groups combined. In both sexes, within single size groups, K increases, on the average, 0.028 per one-year increase in age. This increase is seven to nine times the increase of K with age, when all length groups are combined (0.004 in the males and 0.003 in the females).

The low average value of the coefficient of condition in the longjaw — 0.99 in the males; 1.04 in the females; and 1.02 sexes combined — indicates that this fish belongs to a group with a very slender body form. The grand average value of 1.02 is well below that of 1.13 determined by me (1929) for the Lake Huron herring, the only other Great Lakes species of *Leucichthys* for which coefficients of condition have been published.

VII. SEX RATIO

The sex ratio, expressed both as percentages and as the number of females per 100 males, is given in Table X for each age group as well as for the entire sample. Of 589 longjaws 45 per cent were males and 55 per cent females. When allowance is made for the probability that there was some selective action by the gill net on the two sexes of age groups IV and V, whereby more females than males were taken (the females were on the average somewhat heavier than the males at corresponding lengths), then it may be safe to state that the two sexes are approximately equally abundant in a population composed of the age groups studied.

TABLE X

SEX RATIOS ACCORDING TO AGE OF THE LAKE SUPERIOR LONGJAW AS
DETERMINED FROM THE SAMPLE COLLECTED JULY 17, 1922

The numbers of specimens are shown in parentheses.

Sex	Age group							
	IV	V	VI	VII	VIII	IX	X	IV-X
Males, percentage. . . .	40 (2)	26 (9)	51 (101)	48 (117)	36 (34)	8 (1)	50 (1)	45 (265)
Females, percentage. . .	60 (3)	74 (26)	49 (95)	52 (126)	64 (61)	92 (12)	50 (1)	55 (324)
Females per 100 males	150	289	94	108	179	1,200	100	122

When the percentages or the ratios of age groups VI-IX are compared, it will be noted that the males become relatively fewer than the females with each older age group. In age group VIII there is a sharp decrease in the percentage of males, and in age group IX an almost complete disappearance of males. After the eighth year the males disappear from the catch much more rapidly than do the females. These results form an interesting contrast to those obtained by me for the lake herring (*Leucichthys artedii*) of Lake Huron. In the herring the females decrease in relative abundance with increasing age. This changing sex ratio in the herring was attributed by me to an earlier attainment of sexual maturity by the females and a consequent tendency for them to appear in the commercial catch at an earlier age than do the males. Whether a similar explanation will hold in the case of the male longjaw cannot be stated at this

time, since no information is available on the age at which the male and the female longjaws reach sexual maturity. Hile (1936) gives an interesting discussion on the subject of sex ratios in connection with the cisco (*Leucichthys artedi*) of certain inland lakes in Wisconsin. He found that the females tend to become relatively more abundant as age increases. He was inclined to attribute this shifting in sex ratios to a differential mortality of the sexes and held that the females are inherently better fitted than males to survive adverse environmental conditions. On this basis we would have to believe that in the Lake Superior longjaw the females are more viable than the males, but that in the closely related herring of Lake Huron the males are the more viable.

VIII. SUMMARY

1. This study was based on the determination of age and the calculation of growth from the scales of 589 Lake Superior longjaws (*Leucichthys zenithicus*) taken with gill nets from Lake Superior on July 17, 1922.

2. The sample was composed of fish of age groups IV-X. Age group VII predominated, comprising 41.3 per cent of the catch. The bulk (90.7 per cent) of the sample was composed of individuals of age groups VI-VIII.

3. The bulk (93.2 per cent) of the sample ranged between 230 millimeters (total length 11 inches) and 284 millimeters (total length 13.6 inches) in standard length, with the mode at 252 millimeters (total length 12 inches).

4. The males of the sample averaged 251 millimeters in standard length (total length 12 inches) and 5.6 ounces in weight, the females 255 millimeters (total length 12.2 inches) and 6.1 ounces, and both sexes together 254 millimeters in length (total length 12.1 inches) and 5.9 ounces in weight.

5. In terms of length the two sexes grew at the same rate, but the females were somewhat heavier than the males at corresponding lengths and ages.

6. The longjaw grows relatively very rapidly in length during the first year, when its growth increment (80 millimeters) is on the average about three times as large as that during any one of the next five years, and when about 32 per cent of its total growth in length is completed.

7. In weight the longjaw grows relatively very slowly during the first four years, when only about 39 per cent of its total growth in weight is completed. From the fifth to the sixth year there is a very rapid increase in weight — about 53 per cent in the males and 66 per cent in the females. From the point of view of the commercial fisheries it would be profitable, therefore, to protect the longjaw until at least its sixth year of life, when it reaches a total length of about 10.3 inches.

8. The computed lengths indicate that the various year classes grew at approximately the same rate. This may be explained by the fact that throughout its entire life the longjaw inhabits the deeper waters of Lake Superior, where the seasonal temperatures vary little from year to year.

9. There is "growth compensation" in the Lake Superior longjaw.

10. A curve is presented that shows for the longjaw the relationship between length, both standard and total, and weight, expressed in grams and ounces.

11. Standard lengths in millimeters may be converted to total lengths in inches by dividing the former by 20.93 (25.4×0.824).

12. The coefficient of condition, K , increases as the age of the fish of a single size group (fish of same length) increases, and decreases as the length of the fish of an age group (fish of same age) increases. Slow growth, therefore, is correlated with a relatively high value of the coefficient of condition. The most slowly growing longjaws were in the best condition.

13. The low average value of the coefficient of condition (1.02) indicates that the longjaw is a fish of very slender body form.

14. Of the 589 longjaws 45 per cent were males and 55 per cent were females. A detailed analysis of the data suggests that the two sexes are approximately equally abundant in the population. There is a changing sex ratio with age; the males become relatively fewer than the females with each older age group.

LITERATURE CITED

- BAJKOV, ALEXANDER. 1930. Fishing Industry and Fisheries Investigations in the Prairie Provinces. Trans. Am. Fish. Soc., 60: 215-237, figs. 1-6.
- HILE, RALPH. 1936. Age and Growth of the Cisco *Leucichthys artedii* (Le Sueur) in the Lakes of the Northeastern Highlands, Wisconsin. Bulletin of the Bureau of Fisheries, 48: 211-317, figs. 1-11.
- KOELZ, WALTER. 1929. Coregonid Fishes of the Great Lakes. Bulletin of the Bureau of Fisheries, 43 (1927), Part II, 297-643, figs. 1-31.
- VAN OOSTEN, JOHN. 1929. Life History of the Lake Herring (*Leucichthys artedii* Le Sueur) of Lake Huron as Revealed by Its Scales, with a Critique of the Scale Method. Bulletin of the Bureau of Fisheries, 44 (1928), 265-428, figs. 1-43.

INDEX OF AUTHORS AND SUBJECTS

	PAGE
Additions to the Flora of Chippewa County, Michigan. FREDERICK J. HERMANN	85
Additions to the Flora of Washtenaw County, Michigan. II. FREDERICK J. HERMANN	91
Age, Growth, and Morphometry of the Cisco, <i>Leucichthys artedii</i> (Le Sueur), in Blind Lake, Washtenaw County, Michigan. GERALD P. COOPER .	563
Age, Growth, and Sex Ratio of the Lake Superior Longjaw, <i>Leucichthys zenithicus</i> (Jordan and Evermann) (The). JOHN VAN OOSTEN.....	691
AMBROSE, ALICE L. The Nature of the Question, "Are there Three Consecutive 7's in the Expansion of $H?$?"	505
Anatomy of the Leaf Transition Region of <i>Urginea maritima</i> . DOROTHY CHAPMAN CARPENTER	27
Anyphaenidae of Barro Colorado Island, Panama Canal Zone. ARTHUR M. CHICKERING.....	541
AUSTIN, J. PERRY. Minimum Intensity of Artificial Illumination Effective in Supplementing the Normal Photoperiod.	25
BAXTER, DOW V. Some Resupinate Polypores from the Region of the Great Lakes. VIII	275
BAY, JAMES WILLIAM. Glacial-Lake Levels Indicated by Terraces of the Huron, Rouge, and Clinton Rivers, Michigan	411
BERGQUIST, STANARD G. The Cambrian-Ozarkian Contact in Alger County, Michigan.....	421
Biology of the Boxwood Leaf Miner (<i>Monarthropalpus buxi</i> Labou) in Michigan. DONALD T. RIES	665
BIRD, RONALD L. Tests Used in Comparing Back Pumps.....	297
BLANCHARD, FRANK N. Eggs and Natural Nests of the Eastern Ringneck Snake, <i>Diadophis punctatus edwardsii</i>	521
BOTHWELL, LYMAN D. The Geographic Factor in the Distribution, Trends, and Peaks of the Population of Puerto Rico, 1900-1930.....	321
Bryophytes of the Porcupine Mountains, Ontonagon County, Michigan. GEORGE E. NICHOLS AND WILLIAM C. STEERE.....	183
BURT, CHARLES E. Contributions to Texan Herpetology. V. Spiny and Scaly Lizards (<i>Sceloporus</i>)	533
Cambrian-Ozarkian Contact in Alger County, Michigan (The). STANARD G. Bergquist	421
CARPENTER, DOROTHY CHAPMAN. Anatomy of the Leaf Transition Region of <i>Urginea maritima</i>	27
Cell Outgrowths from Wounded Surfaces of Plants in Damp Atmospheres. CARL D. LA RUE	123

	PAGE
CHICKERING, ARTHUR M. Anyphaenidae of Barro Colorado Island, Panama Canal Zone	541
Chorology of the Claremont-Springfield Region in the Upper Connecticut Valley in New Hampshire and Vermont (The). STANLEY D. DODGE .	335
Contributions to Texan Herpetology. V. Spiny and Scaly Lizards (<i>Sceloporus</i>). CHARLES E. BURT	533
COOPER, GERALD P. Age, Growth, and Morphometry of the Cisco, <i>Leucichthys artedi</i> (Le Sueur), in Blind Lake, Washtenaw County, Michigan	563
CREASER, CHARLES W., AND METCALF, JESSIE L. Iodine and the Production of Permanent Tadpoles in the Frog (<i>Rana pipiens</i>)	661
DARLINGTON, HENRY TOWNSEND. Vegetation of the Porcupine Mountains, Northern Michigan. Part II. Floristics	33
DE BRUINE, HARVEY. The Embryology of the Spleen in <i>Amia calva</i>	573
Decade and a Half of American Agricultural Policy (A). HARALD S. PATTON	259
DICK, W. BRUCE. A Study of the Original Vegetation of Wayne County, Michigan	329
DODGE, STANLEY D. The Chorology of the Claremont-Springfield Region in the Upper Connecticut Valley in New Hampshire and Vermont...	335
DODGE, STANLEY D., AND WILSON, LEONARD S. The Umland of Howell, Livingston County, Michigan	355
DOW, KENNETH W., AND SCOTT, IRVING D. Dunes of the Herring Lake Embayment, Michigan	437
Dunes of the Herring Lake Embayment, Michigan. IRVING D. SCOTT AND KENNETH W. DOW	437
DUNHAM, HARMAN W., AND GRANICK, SAM. Growth Responses of Various Plants to Indole 3-N-Propionic Acid	69
EGGLETON, FRANK E. Productivity of the Profundal Benthic Zone in Lake Michigan	593
Eggs and Natural Nests of the Eastern Ringneck Snake, <i>Diadophis punctatus edwardsii</i> . FRANK N. BLANCHARD.....	521
Embryology of the Spleen in <i>Amia calva</i> (The). HARVEY DE BRUINE...	573
ESCHMEYER, R. WILLIAM. Some Characteristics of a Population of Stunted Perch	613
EYRE, FRANCIS H., AND YOUNG, LEIGH J. Release Cuttings in Plantations of White and Norway Pine.....	301
Formation of Periderm in the Endosperm of <i>Crinum asiaticum</i> . JAMES MERRY	159
French Election of 1871 (The). RUDOLPH A. WINNACKER	477
Fresh-Water Algae from Texas. LOIS C. LILLICK	141
Functional Areas of Detroit, 1890-1933. LEONARD S. WILSON	397
Further Observations and Statistics on the Flight of Fishes. CARL L. HUBBS	641
Geographic Factor in the Distribution, Trends, and Peaks of the Population of Puerto Rico, 1900-1930 (The). LYMAN D. BOTHWELL	321
Glacial-Lake Levels Indicated by Terraces of the Huron, Rouge, and Clinton Rivers, Michigan. JAMES WILLIAM BAY.....	411
GLENDINNING, ROBERT M. The Slope and Slope-Direction Map	359

Index of Authors and Subjects

715

PAGE

GRANICK, SAM, AND DUNHAM, HARMAN W. Growth Responses of Various Plants to Indole 3-N-Propionic Acid	69
Growth Responses of Various Plants to Indole 3-N-Propionic Acid. SAM GRANICK AND HARMAN W. DUNHAM	69
GUSTAFSON, FELIX G. Proliferation and Renewal of Growth in Suppressed Fruits in Tomatoes	79
GUSTAFSON, FELIX G. When Does a Pine Tree Complete Its Seasonal Growth?	83
HALFERT, ELIZABETH, AND JANSON, ELSIE. A Pollen Analysis of a Bog in Northern Ontario	95
HALL, ROBERT BURNETT. A Map of Settlement Agglomeration and Dissemination in Japan	365
HERMANN, FREDERICK J. Additions to the Flora of Chippewa County, Michigan	85
HERMANN, FREDERICK J. Additions to the Flora of Washtenaw County, Michigan. II.	91
HICKIE, PAUL. A Preliminary Report on the Past and Present Status of the Moose, <i>Alces americana</i> (Clinton), in Michigan	629
HUBBS, CARL L. Further Observations and Statistics on the Flight of Fishes.	641
Iodine and the Production of Permanent Tadpoles in the Frog (<i>Rana pipiens</i>). JESSIE L. METCALF AND CHARLES W. CREASER	661
ISELL, EGBERT R. The Justices of the Peace and the Royal Prerogative in the Reign of James I.	451
JAMES, PRESTON E. The Surface Configuration of South America.	369
JANSON, ELSIE, AND HALFERT, ELIZABETH. A Pollen Analysis of a Bog in Northern Ontario.	95
JAO, CHIN-CHIH. New Marine Algae from Washington.	99
JONES, VOLNEY H. Notes on the Preparation and the Uses of Basswood Fiber by the Indians of the Great Lakes Region.	1
Justices of the Peace and the Royal Prerogative in the Reign of James I (The). EGBERT R. ISELL	451
KANOUSE, BESSIE B. Notes on New or Unusual Michigan Discomycetes. IV.	117
KENDALL, HENRY MADISON. Notes on the Population of France, with Special Reference to the Population of the Aquitain Basin.	373
LA RUE, CARL D. Cell Outgrowths from Wounded Surfaces of Plants in Damp Atmospheres	123
LEVIN, SAMUEL M. Marx vs. Malthus.	243
Liddell's Laws of English Rhythm. AMOS R. MORRIS	485
LILLICK, LOIS C. Fresh-Water Algae from Texas	141
MAINS, EDWIN B. Rusts from the Lower Rio Grande Valley, Texas	153
Map of Settlement Agglomeration and Dissemination in Japan (A). ROBERT BURNETT HALL	365
Marx vs. Malthus. SAMUEL M. LEVIN	243
MERRY, JAMES. Formation of Periderm in the Endosperm of <i>Crinum asiaticum</i>	159

UNIVERSITY OF MICHIGAN PUBLICATIONS

PAPERS OF THE MICHIGAN ACADEMY OF SCIENCE, ARTS AND LETTERS

(Containing papers submitted at annual meetings)

Editors: EUGENE S. McCARTNEY AND ALFRED H. STOCKARD

Size, 24.2×16.5 cm. 8°. Bound in Cloth.

- VOL. I (1921). Pp. xi + 424. \$2.00.
VOL. II (1922). Pp. xi + 226. \$2.00. Bound in paper, \$1.50.
VOL. III (1923). Pp. xii + 473. \$3.00. Bound in paper, \$2.25.
VOL. IV (1924), PART I. Pp. xii + 631. \$3.00. Bound in paper, \$2.25.
VOL. IV (1924), PART II. A KEY TO THE SNAKES OF THE UNITED STATES,
CANADA AND LOWER CALIFORNIA. By Frank N. Blanchard. Pp. xiii
+ 65. \$1.75.
VOL. V (1925). Pp. xii + 479. \$3.00. Bound in paper, \$2.25.
VOL. VI (1926). (Papers in botany only.) Pp. xii + 406. \$3.00. Bound in
paper, \$2.25.
VOL. VII (1926). (No papers in botany.) Pp. xii + 435. \$3.00. Bound
in paper, \$2.25.
VOL. VIII (1927). Pp. xiv + 456. \$3.00. Bound in paper, \$2.25.
VOL. IX (1928). (Papers in botany and forestry only.) Pp. xiv + 597. \$4.00.
Bound in paper, \$2.25.
VOL. X (1928). (No papers in botany or forestry.) Pp. xvii + 620. \$4.00.
Bound in paper, \$2.25.
VOL. XI (1929). (Papers in botany and zoölogy only.) Pp. xii + 494. \$3.50.
Bound in paper, \$2.25.
VOL. XII (1929). (No papers in botany or zoölogy.) Pp. xii + 348. \$3.00.
Bound in paper, \$2.25.
VOL. XIII (1930). (Papers in botany and zoölogy only.) Pp. xii + 603.
\$4.00. Bound in paper, \$2.25.
VOL. XIV (1930). (No papers in botany or zoölogy.) Pp. xv + 650. \$4.00.
Bound in paper, \$2.25.
VOL. XV (1931). (Papers in botany, forestry, and zoölogy only.) Pp. x
+ 511. \$3.50. Bound in paper, \$2.25.
VOL. XVI (1931). (No papers in botany, forestry, or zoölogy.) Pp. x + 521.
\$3.50. Bound in paper, \$2.25.
VOL. XVII (1932). (Papers in botany, forestry, and zoölogy only.) Pp. x
+ 738. \$4.00. Bound in paper, \$2.25.
VOL. XVIII (1932). (No papers in botany, forestry, or zoölogy.) Pp. xiv
+ 623. \$4.00. Bound in paper, \$2.25.
VOL. XIX (1933). Pp. xii + 662. \$4.00. Bound in paper, \$2.25.
VOL. XX (1934). Pp. xvi + 755. \$4.00. Bound in paper, \$2.25.
VOL. XXI (1935). Pp. xvi + 757. \$4.00. Bound in paper, \$2.25.
VOL. XXII (1936). Pp. xiv + 717. \$4.00. Bound in paper, \$2.25.

*Orders should be addressed to The Librarian, University of Michigan,
Ann Arbor, Michigan.*

